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A mechanical evaluation of Alaskan white spruce

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A MECHANICAL EVALUATION OF ALASKAN WHITE SPRUCE

A

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A MECHANICAL EVALUATION OF

ALASKAN WHITE SPRUCE

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ABSTRACT

This project serves to demonstrate the usefulness of Alaskan White Spruce as a construction material. This is done through the development of allowable strength values for design purposes. Such values allow engineers to design structures using Alaskan White Spruce, increasing the usefulness of the wood species.

The mechanical properties of Alaskan White Spruce are investigated. Summaries of the mechanical properties and of subsequently developed allowable structural design values are given. Included are discussions of the Alaskan White Spruce species, general wood behavior, mechanical testing of wood, statistical data analysis, and allowable property development. Results are compared against the work of other researchers. Appendices of test data are given.

Test results and subsequent data analysis indicate Alaskan White Spruce possesses strength similar to Douglas-Fir/Larch lumber and higher strength than Spruce/Pine/Fir type lumbers. This indicates that Alaskan White Spruce may have considerable worth as a construction material.

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CHAPTER 1: INTRODUCTION

1.1 Background & Objective of Project

The total land area of Alaska encompasses approximately 365 million acres. Of this area, about 33% is forested, giving a total of 119 million acres of woodlands (11). The forest land may be divided into two geophysical areas, Coastal, and Interior Alaska. Together these two areas support commercially viable populations of several species of softwoods and hardwoods. The object of the research reported herein is the determination of the mechanical properties of one Alaskan softwood, White Spruce. This species will subsequently be referred to as Alaskan White Spruce, to distinguish it from White Spruce grown elsewhere.

Typical uses of softwood timber include pulp production, chemical production, construction lumber, poles, and posts. Alaskan White Spruce is well suited for use in any of these applications, but for the most part has been exported as logs and chips to foreign markets. Alaskan White Spruce has not been exported as finished lumber for various reasons, including the relatively high cost of producing lumber from Alaskan White Spruce which makes it uncompetitive with other sources of lumber. Also, the typical White Spruce tree was considered too small for the solid-sawn lumber market that constituted the majority of softwood utilization in the past.

This is all about to change; harvests of old growth forests are declining, and the timber industry is being forced to harvest second-growth forests consisting of fast growing, but small diameter trees comparable in size to Alaskan White Spruce. Furthermore, the price of lumber has increased dramatically in recent years, possibly to the point of making production of Alaskan White Spruce lumber economically feasible. As such, Alaskan White Spruce may become as useful for lumber production as the traditional species of Douglas-Fir or Southern Pine grown in the contiguous United States.

Alaskan White Spruce has several advantages over timber from sources outside of Alaska. Spruce grown in Alaska grows slowly due to the climate, resulting in denser, stronger timber. Alaska-grown timber is closer to foreign markets than the contiguous United States. Also, Alaskan White Spruce forests are not considered to be old-growth forests, as the vast majority of white spruce timber in Alaska never reaches 150 years of age, due to fire or rot (11).

Forestry operations within the Alaskan White Spruce forests can actually be beneficial to forest and wildlife populations through the reduction of fire load, and improvement of habitat due to creation of browse and cover which is choked out as the spruce stands mature. This habitat can not re-establish itself until the White Spruce cover is removed by fire or logging.

Current disadvantages inherent in the use of Alaskan White Spruce lumber fall into two categories: infrastructure, and technical. Access to the majority of the Alaskan White Spruce forests is currently limited by lack of transportation networks. The current production capacity of existing lumber mills in the Alaskan White Spruce forests is inadequate to produce the volumes of lumber needed within Alaska (30), let alone support an export market for finished lumber. Additionally, some of the smaller Alaskan lumber mills tend to be inconsistent in the quality or size of their product, few mills have planers needed to produce surfaced lumber, and few mills have drying kilns in which to season their lumber.

Technical problems in the use of Alaskan White Spruce center around two issues: the lack of allowable design values for Alaskan White Spruce, and the absence of "Alaska Grading

Rules" or other rules which would govern the grading and quality of produced lumber. Until both of the issues are resolved, it is not possible to effectively use Alaskan White Spruce in design or construction.

Most of the timber harvested in Alaska is exported out of Alaska as round logs, cants, and pulp designated for foreign markets where it is processed into lumber or other products. In 1991, more than 520 million board feet (mmbf) of assorted softwood logs were exported from Alaska. Average value of the exported logs was $546 per thousand board feet (mbf) (40). Some of the exported logs are capable of being cut into high quality, clear lumber. This lumber can sell for as much as $1200 per mbf in the contiguous United States (40). Estimates of the amount of Alaskan White Spruce exported vary widely from 20 to 35 million board feet, some of which was exported as chips (9,23,39).

An estimated 100 million board feet of finished lumber is consumed annually in Alaska, the vast majority of it imported into Alaska from Canada and the contiguous United States (30). Alaska does not manufacture enough lumber for its own use, but exports 520 million board feet of raw material in the form of sawlogs.

In an effort to remove some of the obstacles associated with the use of Alaskan White Spruce, this research project sets out to develop allowable design values for Alaskan White Spruce lumber. Such design values would aid engineers and the construction industry, possibly increasing the demand for Alaskan White spruce.

To develop the allowable design properties for Alaskan White Spruce, several tasks had to be accomplished. First, facilities and apparatus for the mechanical testing of wood had to be developed. Second, procedures for sample collection, handling, and processing had to be developed in order than timber might actually be obtained and tested. Third, procedures for analyzing the test data had to be reviewed and otherwise developed such that the test results might be converted into allowable design values. The procedures and equipment developed here may have additional use in the future testing of other Alaskan wood species.

1.2 Alaskan White Spruce

1.2.1 Description of the Resource

White Spruce (*Picea glauca*(Moench)Voss) is a coniferous softwood species with a long history of use for lumber and pulpwood products. Like most conifers, White Spruce does not flower, but rather produces its seeds in cones. It is related to other spruce species, in particular Sitka Spruce, Red Spruce, Black Spruce, and Engelmann Spruce. The heartwood and sapwood are practically white, and are not easily distinguished once the wood has seasoned. The wood is nonporous, with a fine texture that can be milled and worked easily (15). Alaskan White Spruce is botanically identical to other white spruces, but has somewhat different properties than White Spruce from the contiguous United States. These differences are believed to be related to factors which influence the growth of the spruces, particularly climate and length of growing season.

White Spruce may be found in many of the Northern States, particularly the Northeastern States and those bordering the Great Lakes. White Spruce is used mainly as a pulp wood, although lumber is manufactured from White Spruce under the designation Eastern Spruces (17). White Spruce forests extend through much of Canada and into Alaska. In Alaska, White Spruce is found typically in the interior, although it does grow out to tidewater in several places (15,16). Alaskan

White Spruce is a hardy species, capable of thriving north of the Arctic Circle where it grows densely in the great boreal forests of Canada and Alaska (19).

One-third of the land in Alaska is forested, for a total forest area of 119 million acres. The forests may be divided into two areas, 13.2 million acres of old-growth coastal forests, and 106 million acres of interior forests where Alaskan White Spruce grows. The spruce prefers the warmer south, east, and west facing slopes along river valley bottoms. The interior region has warm, dry summers with typical rainfalls in the range of 10 to 30 inches. Much of the interior forest is at a high latitude, and as a result much of the forest receives light 24-hours a day during the growing season. Thus, while the growing season may be as short as 100 days, it is an intense one (11). Ground temperatures are low, as the winters are very cold, and permafrost soils are very common. This results in shallow root systems. The dry, warm summers encourage fire, which has kept the interior forests from reaching old growth status. Few areas in the interior forests have escaped fire within the last 250 years (22).

White Spruce grows from a seed produced in cones, which open at maturity to disseminate the seed upon the wind. If seed lands on mineral soil or the ashes of burned areas, the seeds readily germinate and grow new spruce trees; conversely, germination is inhibited in organic soils and humus (22). Alaskan White Spruce is shade tolerant, and is quite capable of out competing other vegetation, eventually shading and killing the vegetation off as the spruce grows. The spruce then grows more rapidly as more light becomes available, to equal or exceed the height of the Alaskan hardwoods, such as Birch (22). As the hardwoods die from age or lack of light, the spruce assumes the dominant position in the forest, and can remain there for 180 to 350 years, at which point the decaying spruce forest may be replaced by Alders or Black Spruce, depending on the soil temperatures (13,37).

Brush and hardwoods such as Birch can not invade established spruce stands, so old spruce forests are often poor habitat, providing little browse. Old spruce forests are also typically full of damaged and rotting trees with little commercial value.

Forest land covered with old spruce is reclaimed and made productive again by fire. Alaskan White Spruce is very susceptible to destruction by fire, as the trees have thin, easily damaged bark, branches which extend nearly to the ground, and very shallow roots due to the cold soils present in many areas. Discarded cones and cone scales also form mounds around the trees and while providing food for rodents, also encourage persistent, ground-clearing fires (22).

White Spruce is at a disadvantage when compared with other vegetation; White Spruce cones open at maturity and as such, the seed is destroyed during fires while many other species can survive fire. Seed to reforest an area will be transported in from adjacent or distant tree populations, however White Spruce does not produce abundant seeds every year. As a result, grasses and weeds begin growing very quickly, followed by fast growing willows and brush, which in turn are followed by slower growing hardwoods such as Cottonwood and Birch (11). This rapid growth of brush and hardwoods provides excellent browse and cover for wildlife, until once again the spruce trees invade and ultimately dominate the forest.

Because of the dynamic nature of the interior forests, harvests of Alaskan White Spruce timber may be very compatible with the natural progression of the forest, as harvests would take the place of the fire cycle. This allows the commercial use of the spruce instead of its destruction. Harvests of spruce would remove nutrients from the soil, in that ashes from burned trees are no longer available. This loss is minimized by the practice of limbing the trees where they are harvested, and either burning the limbs or letting them decay on the surface. In some cases, an occasional application of fertilizer may be beneficial. Efforts to prevent the erosion of soil are necessary, as are policies meant to prevent the creation of eyesores by extensive logging. Patch cutting, and the creation of buffer zones around lakes, streams, towns, and other sites of interest are alternatives that can minimize the impacts associated with logging.

The rotation age is defined as the time in years needed to establish and grow timber crops to a specified condition of maturity (42). It is the time that must pass before an area may be reharvested. Rotation age may be selected to maximize production of timber volumes, or to maximize development of trees of desired sizes. It may also be selected to maximize financial gain, or to coincide with natural forest death. The rotation age varies with the desired results, and with growing conditions. For Alaskan White Spruce, rotation ages vary from 70 to 150 years (13). Currently, a period of 130 years is recommended for use in the Fairbanks area to approximate natural rotation (42).

1.2.2 Resource Development

While the interior forests encompass 106 million acres of Alaska, only 13 percent or 13.5 million acres is considered to be commercial forest land capable of producing more than 20 cubic feet of wood per acre each year (21). Of the commercial forest land, 50 percent or 6.8 million acres is of the Alaskan White Spruce type (21).

Alaska White Spruce grows along river valley bottoms in the central part of Alaska north of the Alaska Range, in particular the Tanana Valley, the Kuskokwim Valley and the Yukon Valley. Spruce also grows over much of the Susitna Valley and Kenai Peninsula, where productive stands cover a higher percentage of the total area than in the remainder of the interior (11,30). Figure 1.1 is a map showing the location of the commercial timberlands in Alaska; much of the growth in the central part of the state is Alaskan White Spruce.

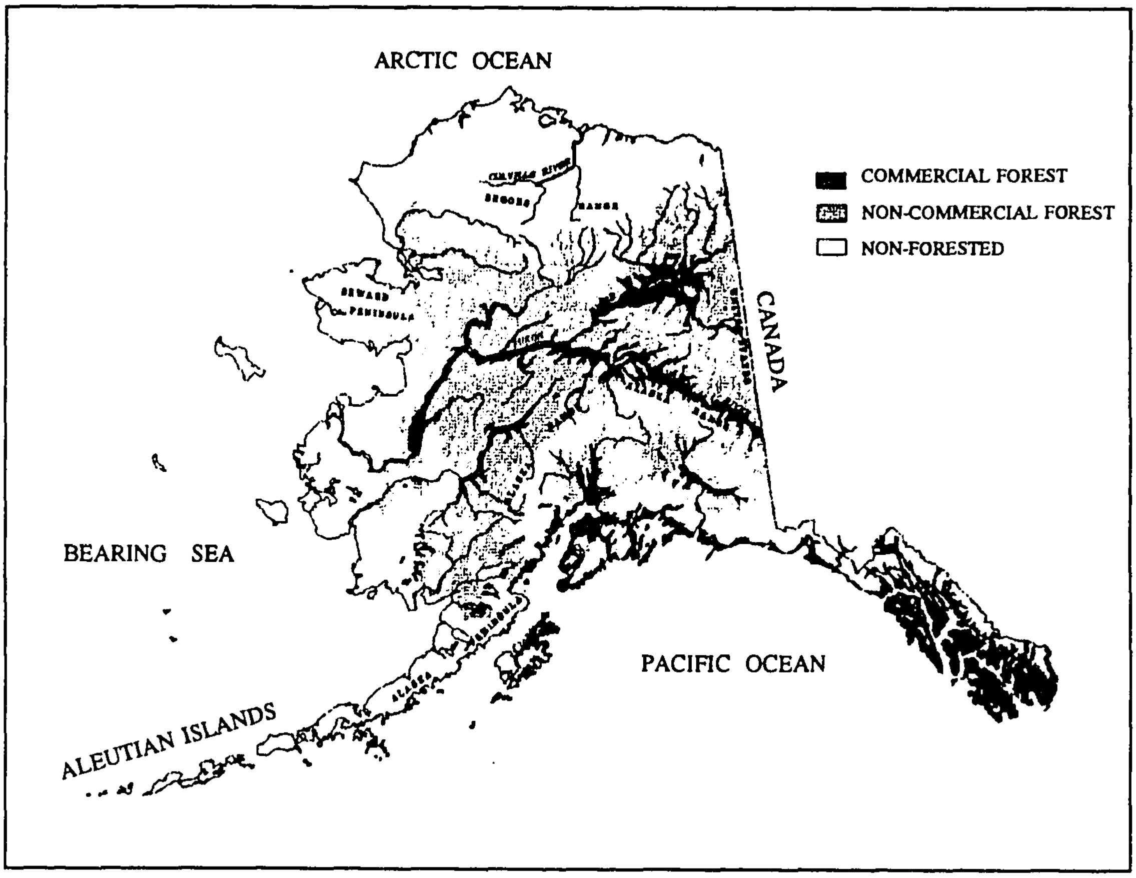

FIGURE 1.1: COMMERCIAL FOREST LAND IN ALASKA (11)

To form a conservative estimate of annual Alaskan White Spruce production, a value of 15 cubic feet/acre/year will be used here; this figure is reduced from the commercial definition of 20 cubic feet/acre/year to account for understocked stands and the presence of other tree species within the White Spruce type forest. With 6.8 million acres of forest, the estimated production of Alaskan White Spruce on available and reserved lands is at least 100 million cubic feet/year. This is some 400 million board feet per year of lumber, based on the conversion ratio of 4 board-feet per cubic foot recommended for use in the Fairbanks, Alaska area (42). This is the total production possible annually, however the amount of production which is actually available for use is currently quite a bit smaller. Problems in the harvest of the extensive Alaskan White Spruce resource are found in the areas of land ownership, access, and manufacturing capability; these problems are discussed below.

Of the 365 million acres contained with Alaska, 104 million acres were granted to the state in its statehood act of 1958. The selection and patenting of these 104 million acres has not been completed yet, although it is anticipated the transfer of the lands will be completed by the year 2000 (21). Most of the remaining land within Alaska was allocated through two acts, the Alaska Native Claims Settlement Act (ANCSA) of 1971 which awarded Alaska Natives 44 million acres of land, and the Alaska National Interest Lands Conservation Act (ANILCA) of 1980 which designated 104 million acres for addition to the National Parks and Forests systems. Less than 1% of land in Alaska is privately owned (30).

As a result of the above legislation, the State of Alaska owns roughly 30 percent of the commercial forest in interior Alaska, about 4.2 million acres. Of this land, 1.9 million acres is of the White Spruce type (21). The various native corporations, and private individuals own another 5.5 million acres of commercial grade forest land, containing 3.6 million acres of White Spruce type forests (21). Thus, a total of 5.5 million acres of available, commercial grade White Spruce type forest exist in Alaska. The amount of the commercial forest land that will actually be used for timber harvests depends on the desires of the land owners; while some of the native corporations may be interested in logging operations, other corporations will undoubtedly have other uses for their lands.

The State of Alaska has expressed some interest in commercial logging in the interior by the creation of the Tanana Valley State Forest, containing 1.8 million acres (34). The State also issues timber sale permits on lands designated for "multiple use".

Access to the Alaskan White Spruce forests is another factor limiting development of the resource. Three major land transportation arteries are used in Interior Alaska: the Parks Highway, the Richardson Highway, and the Alaska Railway. Transport along the major rivers is also used. These routes provide access to the major timber producing areas, but to actually harvest the timber requires considerable investment in the development of local access roads. Transportation techniques which have worked successfully include the use of winter roads and ice bridges stabilized by the cold interior winters. This is an environmentally sound technique, but prevents year round harvests, and requires work in difficult winter conditions. Establishing networks of logging roads into selected forest areas would speed development of the Alaskan White Spruce resources.

The current capacity of lumber mills in interior Alaskan forests also limits the domestic use of Alaskan White Spruce. Interior Alaska has about 200 sawmills, however most of these are very small mills serving local communities (30,35). Total production of lumber is the interior is less than 20 million board feet per year (30), with production of only 5 to 6 million board feet in some years (35). This lumber suffers from lack of recognized grading and quality control rules. The lumber may also be irregular in size. However, the rough and green lumber can be competitive with imports of similar products (30). In many cases, though, the desired product is seasoned, finished lumber and most mills do not have the planers needed to surface lumber. Few drying kilns are available for production of seasoned lumber.

Expansion of current capabilities is needed in order to supply the Alaska construction markets, and develop the spruce resource. Various alternatives are possible, ranging from a large number of small sawmills each producing 4000 board feet per week to be kiln dried and surfaced at regional cooperative yards, to a small (5+) number of large production mills with their own seasoning and surfacing facilities (30). Modern equipment with thin saw kerfs would maximize recovery of lumber from harvested timber.

In spite of the problems in developing the Alaska White Spruce timber resource, development of about 25 percent of the spruce timberlands would be sufficient to produce 100 million board feet of finished lumber annually on a sustainable basis; this figure is based on the 400 million board feet annual possible production discussed in this section. This volume would satisfy the vast majority of local lumber consumption. Benefits of this development include the creation of jobs, and a more stable economy.

Forest scientists have concluded that under normal management techniques, average growth rates of 30 cubic feet/acre/year could be expected, with rates to 45 cubic feet/acre year for intensive management (30). Further gains might be realized by deliberate conversion of high yielding land to White Spruce by planting and other silviculture practices, possibly using genetically altered stock, ensuring a high yield, high quality local supply of timber (30,35).

1.3 Wood as a Material

Wood is an extremely important construction material which has been used since ancient times. Currently, more wood is used in construction every year than steel or concrete (32). Wood science and engineering technology have progressed to the point that the same amount of wood needed to build a 320 ft^2 log cabin can be used to construct a 3500 ft^2 home, with enough surplus material left after cutting the lumber to manufacture a 30 year supply of paper for the family living in the house (32). Unfortunately, wood is also a complex substance, with some properties and behaviors unlike many other construction materials.

1.3.1 Structure

Wood is composed of hollow tubular cells made of cellulose that are arranged parallel to each other and to the long axis of the tree. These tubular cells are cemented together by lignin polymers. The cells are arranged in multiple rows and layers, thus making up the product we know as wood. A typical cell in a softwood will range in length from one-eight to one-third of an inch in length (17). Other wood cells, referred to as ray fibers, run in radial directions from the center of the tree outward, serving to tie the longitudinal fibers together.

Two types of wood are present in a tree, the sapwood and the heartwood. The sapwood is the part of the tree between the bark and the heartwood. The heartwood forms most of the wood present in a tree and consists of dead wood cells which serve to support the tree. The sapwood is the living part of the tree, which provides food storage, and transports water and nutrients within the tree. The outermost layer of the sapwood is the cambium, the layer of cells which produces new wood fibers and bark. The cambium is covered by phloem, which transports water and nutrients up the tree, and bark, which serves as a protective covering against moisture loss and insect attack. A tree grows when the cambium produces new wood cells to replace wood cells dying at the heartwood/ sapwood interface.

Trees typically add one layer of wood to their diameter each year, the thickness of which depends on species, temperature, and the availability of water, light, and nutrients. These factors also effect the quality and strength of the growing wood. In regions with marked changes between the seasons, trees generally grow quickly during the relatively wet spring, and then more slowly during the drier summer months. This results in the formation of the familiar growth rings, with the springwood (or earlywood) being less dense and lighter colored than the more dense and darker colored summerwood (or latewood).

1.3.2 Physical Properties and Behavior

The mechanical properties of wood are strongly influenced by the fibrous nature and orientation of the cells contained in the wood. The physical characteristics and arrangement of the cells affect the strength, stiffness, and shrinkage properties of wood.

Wood is an orthotropic material. This means that its mechanical properties depend upon the direction in which they are examined (18,32). Three orthogonal axes are used to described the mechanical properties of wood. The longitudinal axis is parallel to the wood grain. The radial axis is parallel to the ray fibers in the wood, and is thus perpendicular to the growth rings. The tangential axis is tangent to the growth rings. Figure 1.2 shows the three orthotropic axes used to describe behavior in wood.

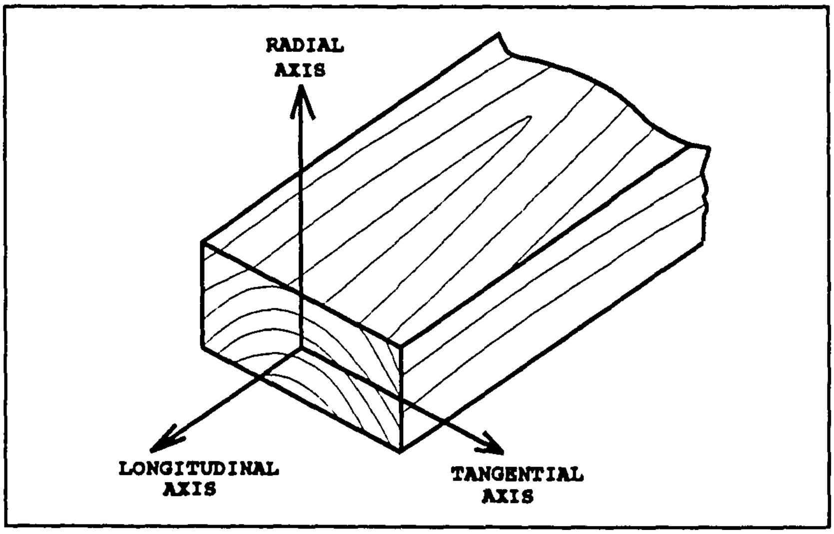

FIGURE 1.2: ORTHOTROPIC AXES IN WOOD

As a wood cell is a hollow tube, it is very efficient in resisting compressive or tensile forces parallel to its length (32). Conversely, loads applied to the side of a wood fiber crush the cells easily. Thus, wood behavior differs greatly between parallel to grain, and perpendicular to grain loading. The behavior perpendicular to grain is further affected by the reinforcing ray fibers; response to a perpendicular load will vary depend on whether the load acts along (radial loading), or across the ray fibers (tangential loading). Furthermore, the type of loading will effect the strength; for example, compressive strength perpendicular to grain is much higher than tension perpendicular to grain. This occurs as the compressive load results in fibers being crushed, while in the case of tension perpendicular to grain, fibers are being pulled apart.

With regard to shrinkage, a wood fiber changes more in diameter than in length when the moisture content changes. This means that shrinkage perpendicular to the grain will be greater than shrinkage parallel to the grain. Also, because of the presence of the ray fibers, the shrinkage measured in the two perpendicular directions differs. Tangential shrinkage is the greatest, while shrinkage in the radial direction is somewhat less, as the radial fibers resist the shrinkage.

As a result of the tubular structure of the wood cells, wood has different properties, depending on whether it is loaded in tension or compression, and either parallel or perpendicular to the grain. Wood also has three possible values for modulus of elasticity, and six values of Poisson's ratio (17). Thus, an engineer using wood in structural design must account for multiple behaviors in the material.

The engineer must also account for environmental factors which influence the behavior and strength of wood. These factors include the wood's moisture content, the temperature, and the duration of loading.

Moisture content is a measure of the amount of water present in wood, relative to the weight of the dry wood. Water in the cell walls and cavities effects the strength and stiffness of the wood. This is because the cellulose and lignin polymers that form the wood structure soften or harden in response to changes in moisture content. Thus, a piece of green lumber gains in strength and stiffness as it drys. Conversely, a seasoned member used in a damp location will lose strength and stiffness as it absorbs water; the designer must anticipate these environmental conditions or the member may fail. Equations for determining the strength at different moisture contents are given in Section 5.2.3

Strength in wood is also time dependant. That is, the ability of a piece of wood to carry a given load depends on how long that load is applied to the wood. Tests have shown that wood has the ability to carry substantially greater loads over short durations than for long durations of sustained working stress (26,27). This behavior is related to the plastic behavior of the cellulose and lignin polymers that form the wood.

Load durations for wood design are standardized around a 10 year duration. This is referred to as the "normal" load duration and is given a load duration modifier of 1. Longer load durations receive a smaller modifier, while modifiers for shorter load durations increase up to a value of 2 for impact loadings. Figure 1.3 is a plot showing the adjustment factors used in wood design to account for load duration.

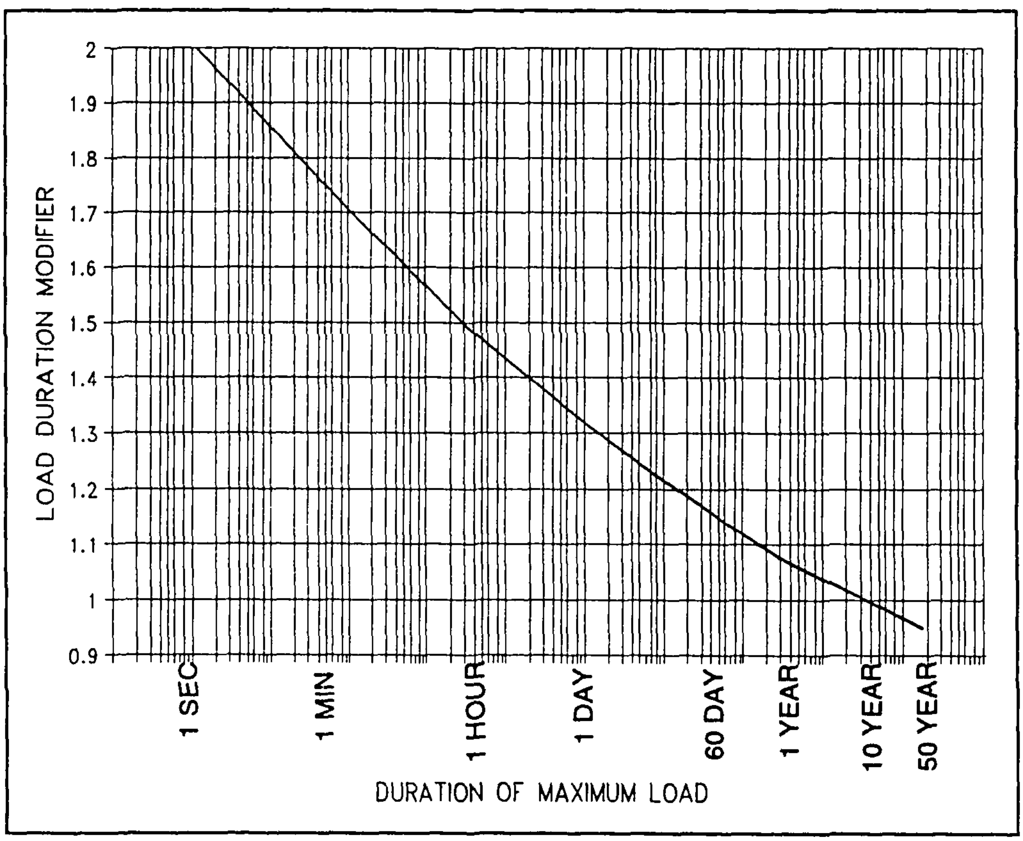

FIGURE 1.3: LOAD DURATION FACTORS

Temperature effects in wood are of less concern than moisture content or duration of loading, but are still significant when wood is used at extreme temperatures. As the temperature increases from 70°F, wood will slowly lose strength, losing about 25 percent of its strength at a temperature of 120°F (17). This effect is reversible, and the strength will return as the temperature drops. However, prolonged use of wood at temperatures above 150°F general results in permanent loss of strength (26,27). Conversely, wood will increase in strength as the temperature decreases, although this phenomenon is less understood than the effects of elevated temperatures.

1.3.3 Defects in Wood

While lumber is a manufactured product, the trees from which the lumber is cut are not manufactured. Rather, trees are grown under highly variable conditions, and contain characteristics such as knots and pitch pockets which are not desirable from an engineering point of view. Further defects are introduced during the cutting and seasoning processes.

The defects present in a given piece of lumber vary widely depending on such factors as size of tree, species and lumber cutting practices. As the defects affect the strength of the lumber, it is necessary to sort pieces of lumber into groups with approximately the same type and degree of defects. Such a group is referred to as a lumber grade, and each grade of lumber has its own particular set of allowable design properties. A "grading rule" is a set of rules describing the extent and type of defects allowed in a particular piece of lumber. Grading rules allow an engineer to specify the strength and quality of lumber to be used in a project and are essential for use of lumber in construction.

Figure 1.4 shows common defects in wood. Defects in wood include: knots, shakes, checks, splits, cross grain, compression wood, wane, and decay. All wood used in construction will have some or all of these defects in varying degrees.

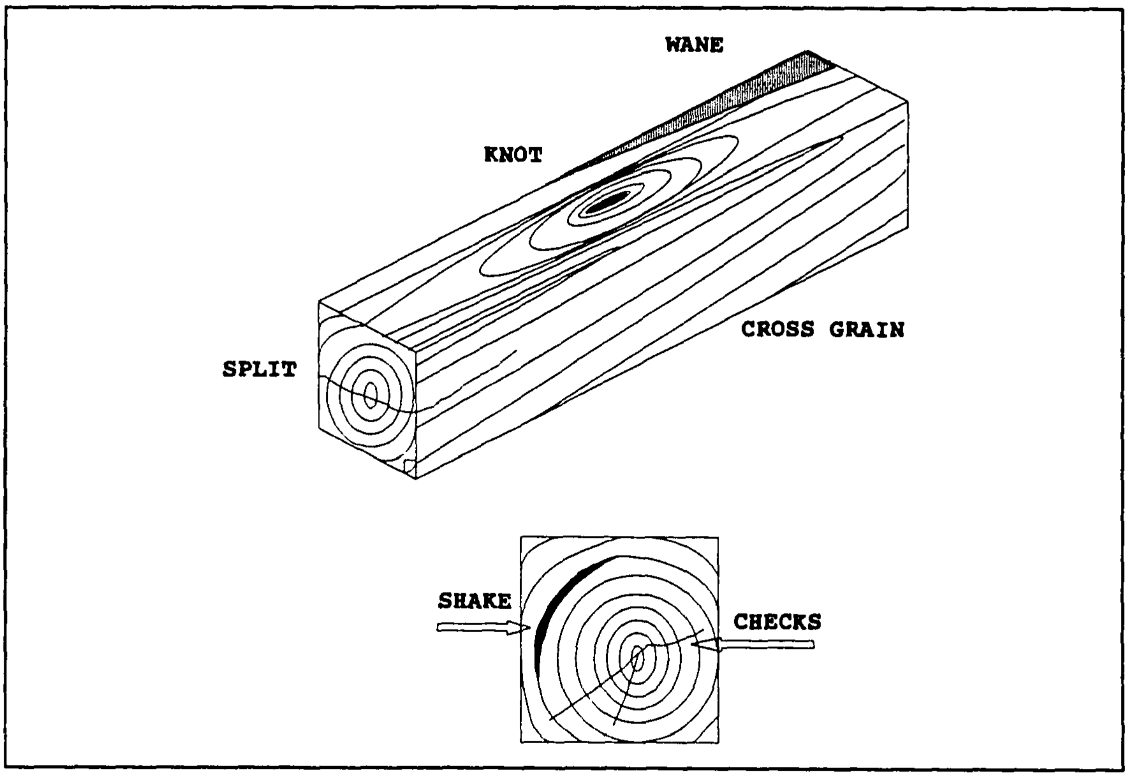

FIGURE 1.4: TYPICAL DEFECTS IN WOOD MEMBERS

Knots are the result of branches growing from the tree trunk. As the tree grows, the trunk grows around the base of the protruding branch, incorporating the branch into the trunk. If the branch was alive when the truck grew around it, the result is referred to as a red knot, which are generally tight and sound. If the branch was dead when the trunk grew around it, the knot is referred to as a black knot. Black knots are often lose, and contain bark or decay. In any case, a knot causes a loss of section in a piece of lumber and changes the grain around the knots. The exact effect a knot has on the strength and stiffness of a member depends on its size and location.

Shakes, checks, and splits are all cracks in a piece of lumber resulting from various causes including mechanical force, drying, and growing conditions. A shake is a separation between two growth rings of a tree. If this occurred while the tree was growing, the shake fills with sap, and a pitch pocket results. A check is a crack running across growth rings caused by uneven shrinkage of the wood in the tangential and radial directions as it seasons. A split is a separation of the wood fibers in a member, which runs completely through the cross section. The degree of strength reduction associated with each of these naturally occurring defects depends on the length and size of the defect.

Cross grain in a piece of wood occurs when the wood fibers do not run parallel to the long axis of the board. This defect is measured using the slope of the grain (or deviation) with respect to the member's long axis. Cross grain is a result of both cutting practices, and growth patterns in the individual trees. Some varieties of trees, Alaskan White Spruce included, have a tendency to twist as they grow, resulting in a "spiral grain" effect.

Compression wood is a defect caused by a growing tree's response to load and stress. If a the trunk or branches of a softwood tree are subjected to prolonged lateral load, the tree will form additional or denser wood in the vicinity of load to help resist the load. While this wood is generally harder and denser than the regular growth, the compression wood also has a much higher rate of shrinkage than normal wood. Thus, excessive compression wood in a timber can result in problems with cracking and warpage as the timber seasons.

Wane is the presence of bark in a finished member. This results from the taper present in a tree trunk. As a board is cut from the very edge of a tree, the board may get thinner as the tree tapers resulting in part of the board containing bark. Wane results in a loss of cross section from the board, but as it is usually present only at the ends, it affects mainly compressive and tensile strength. Generally, wane is only allowed in the lowest of lumber grades.

Decay (rot) is the result of fungi growing in wood. As the fungus grows, it produces chemicals which dissolve parts of the wood microstructure and otherwise weaken the wood allowing the fungi to use the nutrients in the wood as food. As the fungi continues to grow, the wood loses more and more strength as more and more of the cross section is affected. The exact loss of strength is difficult to predict, and for this reason only extremely limited decay is allowed in graded lumber. Fungus growth may be prevented by the use of various preservatives, but once present is difficult to control.

An additional factor, while not a defect, must be considered when selecting lumber. This is the problem of nominal versus actual dimensions. Most construction lumber is specified in terms of the size of the rough cut lumber which was surfaced to produce the finished lumber. Thus, the dimensions of rough lumber are the actual member size, while the dimensions of finished lumber are nominally the size of the rough lumber, minus the planing allowance (generally one-half inch). For example, a nominal 2 x 4 inch board will actual measure 1.5 x 3.5 inches, if surfaced on all four faces. Lumber is generally specified based on the nominal dimensions, but design must be based on the actual dimensions as provided by the wood grading agencies. It should also be noted that with respect to lumber the "width" dimension refers to the widest face of a member, while the "thick" dimension refers to the narrowest face of a member.

1.4 Mechanical Testing

To facilitate the use of Alaskan White Spruce in engineering and construction it is necessary to establish the mechanical properties of the timber species. Two classes of testing are performed on timber: destructive, and non-destructive tests. Non-destructive tests are used for automated grading of individual pieces of machine stress rated lumber, whereas destructive tests are used in evaluating the strength and stiffness of a species as a whole.

The goal of mechanical properties testing is to determine how a timber species behaves when subjected to common loads, conditions and situations the timber can be expect to be used in. Thus, it is important to design testing equipment and procedures to emulate real-world situations. Furthermore, to ensure that the values obtained from a test are acceptable to the engineering and wood science communities, it is important that the tests meet established, standardized criteria developed by these communities. Typical tests performed upon timber include bending tests, compression tests, and tensile tests, among others. Data collected during the tests consists of load, and deformation values; this data can be used to predict behavior.

The process of mechanical property testing is somewhat simplified by the use of procedures and equipment as specified by the American Society for Testing and Materials (ASTM). The use of ASTM procedures ensures that test results will be comparable with results obtained by other researchers. For this reason, ASTM procedures were used throughout this research project. ASTM specifies procedures for use with both small, clear samples of timber, and full size, in-grade members.

To ensure that test results are a fair representation of the actual material behavior, it is necessary to test large number of samples in an accurate and repeatable manner. This generally requires that a large number of trees be tested, preferably from several sites if the species is diversified. At least four locations throughout Alaska representative of the typical Alaskan White Spruce producing areas will eventually be sampled. This report contains the results of testing on samples obtained from the first of these sites, from which 30 trees was harvested. From these trees, over 1600 samples were prepared and tested.

Accuracy and repeatability of the testing was maintained by using modern, hydraulic testing equipment with computerized, feed-back type controllers. This equipment continually adjusts itself in response to inputs from sensors that monitor the machine's operating parameters; the result is very accurate, consistent tests.

Equipment was developed to preform the following mechanical tests: Static Bending, Compression Parallel to Grain, Compression Perpendicular to Grain, Hardness, Shear Parallel to Grain, Cleavage, Tension Perpendicular to Grain, Nail Withdrawal, Specific Gravity and Shrinkage in Volume, and Radial and Tangential Shrinkage. Most of these tests study the wood's response to loading, although several of the tests study the response to changing moisture content.

To aid in the testing of the large number of samples needed for mechanical property development, and to increase the accuracy of the testing, the testing equipment and fixtures were equipped with electronic transducers, with the data collected and processed by a computer. This made the testing process more efficient, while eliminating a common source of error caused by the need to visually read mechanical gauges while attempting to record the data on paper.

The mechanical properties testing described within this report is the most recent study of the properties of Alaskan White Spruce, and hopefully represents some of the most modern techniques used in timber testing. The equipment and procedures are described in detail in Chapter 4.

1.5 Data Analysis and Results

In order to make the best use of data obtained by a mechanical testing procedure, analysis of the data is necessary. The data obtained during this research project was analyzed with the intent of obtaining mechanical properties and allowable design properties for Alaskan White Spruce.

Mechanical properties for the species as a whole are obtained from statistical analysis of the individual test results. Requirements for this analysis are given by ASTM and are discussed in detail in Chapter 5. The results of the statistical analysis are mechanical values referred to here as indicator properties, as these values indicate the mechanical properties of the species. These values allow test results for one species to be readily compared with the properties of another species, but only for the specific type of test performed. This is because the indicator values do not necessarily indicate the material behavior in other than the original test conditions.

The indicator values are immensely useful as the majority of timber testing in the United States is done using the same ASTM tests. Furthermore, the indicator values are used as the starting point for the development of allowable design properties.

Typical types of indicator properties include the mean value, which represents the average of the test results and the 5% exclusion limit, which represents a value 95% of the test results can be expected to meet or exceed. Other indicator properties are the coefficient of variation, which describes the consistency of the test results, and the confidence limits which indicate how wide a range of values must be used to be certain a desired value is present in the range.

Allowable design properties for a species are obtained by applying corrections to the indicator properties to account for the differences between testing conditions and actual use conditions. These corrections account for such things as defects in lumber, duration of load application, and moisture content in use. The specific corrections that are used depend upon the general type of test procedures used (small, clear samples or full size, in grade samples), and the specific type of property being developed.

CHAPTER 2: LITERATURE REVIEW

2.1 Background

The United States Forest Service, a branch of the U.S. Department of Agriculture does much of the timber research performed in the United States. This research is done at a number of forest research stations, and at the Forest Products Laboratory (FPL) in Madison, Wisconsin.

The U.S. Forest Service has done much to characterize the various spruce species, although most of this work has concentrated on spruces growing in the contiguous United States. While little of the Forest Service mechanical property research has directly addressed White Spruce grown in Alaska, several documents are of use in studying the mechanical properties of Alaskan White Spruce.

2.1.1 Wood Engineering Handbook

The Wood Engineering Handbook (14,17) authored by the Forest Products Laboratory provides extensive information on many aspects of wood and wood utilization, covering topics ranging from physiology of wood to wood manufacturing technology. Frequently referred to as "The Wood Book", The Wood Engineering Handbook first published in 1940 is periodically updated, and has come to be regarded as representing the state-of-the-art of wood science.

The Wood Engineering Handbook lists mechanical properties for many species of wood, including White Spruce. The data presented for White Spruce is the result of research programs described in Section 2.1.2, and is based mainly upon spruce samples collected in the contiguous United States. Data is also presented for White Spruce imported into the United States from Canada. No recommendations are made in the Wood Engineering Handbook for Alaskan White Spruce.

2.1.2 Forest Service Research Papers

All of the previously existing mechanical property data for White Spruce grown in the United States was produced by the Forest Products Laboratory as the result of two separate studies. These studies provide a basis for comparing the mechanical properties of Alaskan White Spruce, developed during the research project reported herein with the properties developed elsewhere.

2.1.2.1 Research Paper FPL1

U.S. Forest Service Research Paper FPL 1, entitled "Characteristics of Alaska Woods" was published in January of 1963 (15). This paper presents the results of mechanical property tests on eight species of trees which grow in Alaska, and compares these test results with data for the same species grown in the contiguous United States. One of the tree species tested in Alaska was a five tree sample of Alaskan White Spruce, harvested in the Matanuska valley. This is the only sample of Alaskan White Spruce ever tested by the Forest Products Laboratory. The results of this study are reproduced in Table 2.1. The values reported in Table 2.1 are all mean values, and were obtained from tests on small clear samples.

TABLE 2.1: MECHANICAL PROPERTIES OF WHITE SPRUCE

WHITE SPRUCE TEST SITE OR STUDY	SPECIFIC GRAVITY	SHRINKAGE VOL.	SHRINKAGE RAD.	SHRINKAGE TAN.	STATIC BENDING MODULUS OF: RUPTURE	STATIC BENDING MODULUS OF: ELASTIC.	COMP. STRENGTH PARALLEL TO GRAIN	COMP. STRENGTH PERPEND. TO GRAIN	SHEAR STRENGTH PARALLEL TO GRAIN	TENSILE STRENGTH PERPEND. TO GRAIN	HARDNESS LOAD END	HARDNESS LOAD SIDE
UNITS		(%)	(%)	(%)	(PSI)	(KSI)	(PSI)	(PSI)	(PSI)	(PSI)	(LBS)	(LBS)
FPL1: CONTIGUOUS U.S, 1963												
COOS COUNTY, N.H.												
GREEN	0.35	---	---	---	5700	1060	2440	280	680	---	220	240
SEASONED	0.37	---	---	---	9300	1360	5020	460	1130	350	540	440
RUSK COUNTY, WIS.												
GREEN	0.38	14.8	3.7	7.3	5400	990	2550	270	690	200	290	280
SEASONED	0.41	---	---	---	9000	1500	5320	540	770	---	700	530
FPL237: CONTIGUOUS U.S., 1974												
EIGHT STATES												
GREEN	0.33	---	---	---	4995	1141	2349	210	636	---	318	274
SEASONED	0.36	---	---	---	9448	1429	5178	432	972	---	519	409
IMPORTED CANADIAN TIMBER:												
GREEN	0.35	---	---	---	5100	1150	2470	240	670	---	---	---
SEASONED	---	---	---	---	9100	1450	5360	500	980	---	---	---
FPL1: ALASKA STATE, 1963												
MATANUSKA VALLEY												
GREEN	0.39	12.6	5.8	9.1	5700	1150	2720	330	710	230	370	350
SEASONED	0.43	---	---	---	10600	1400	6230	740	1310	390	640	500

The values reported in FPL1 for woods grown in the contiguous United States formed the basis for the mechanical properties values recommended by FPL for several species of wood in their Wood Engineering Handbook until 1974. It is noteworthy that the test results for Alaskan White Spruce are somewhat higher than those for White Spruce harvested in the United States.

2.1.2.2 Research Paper FPL237

U.S.D.A. Forest Service Research Paper FPL 237, titled "Specific Gravity and Mechanical Properties of Black, Red, and White Spruce and Balsam Fir," was published in 1974 (16). This paper presents the results of testing performed with the intent of re-evaluating the mechanical properties of Black, White, and Red Spruces, and Balsam Fir that had been developed by earlier testing. This re-evaluation was requested by various timber utilizers, including the American Plywood Association (APA) and the National Forest Products Association (NFPA). The reasoned for requesting the re-evaluation was that the original sample sources did not necessarily represent the forest resources being harvested. This was due to the broad botanical growth range of each of the reported species, as the original testing procedures had been conducted on very restricted geographical areas.

In order to establish mechanical properties based on a diverse forest sample, the Forest Products Laboratory initiated a random sampling of the four previously mentioned timber species gathering samples from eight states, ranging from Maine to Minnesota. Alaska was not included in this sampling. The procedure utilized in FPL237 resulted in the collection of approximately 33 trees of each of the four species being considered. From a botanical standpoint, this sample was considered to be representative of the forest resource throughout the contiguous United States. Mechanical tests were performed upon these samples, the results of which are presented by Forest Products Laboratory in the research report, and in their Wood Engineering Handbook (17). This new data superseded the earlier data reported in FPL 1 and elsewhere. The results of the tests are reproduced in Table 2.1. In general, the changes to the mechanical properties of contiguous United States grown White Spruce resulting from the research reported in FPL237 were only slight.

Combining the sample sites tested in both Forest Products Laboratory reports, a total of 23 White Spruce stands in eight states were sampled and tested (15,16). Only one Alaskan White Spruce site was tested, and that one not extensively. Additional testing of Alaskan White Spruce is warranted, given the extensive nature of the White Spruce stands in Alaska, each with its own climatic conditions.

2.1.3 Canadian Mechanical Property Values

More recent editions of the Wood Engineering Handbook (17) contain mechanical property data for timber grown in Canada and imported into the United States. Mechanical property values for White Spruce grown in Canada is reproduced in Table 2.1. As much of Canada possess a climate similar to that of Interior Alaska, mechanical properties values for Canadian grown White Spruce may be useful for comparison with Alaskan White Spruce values.

Referring to table 2.1, it can be seen that the values for Canadian-grown White Spruce are similar or slightly higher than values for contiguous United States-grown white spruce. Note that the Canadian values are less than the values obtained in the Matanuska valley testing. No information regarding the quantity of Canadian White Spruce tested is available in the Wood Engineering Handbook.

2.1.4 National Design Specification

Allowable design values for timber as used in engineering practice may be found in the National Design Specification for Wood Construction (NDS) produced by the National Forest Products Association (26,27). The allowable design values are obtained through modification of property indicator values through the use of factors accounting for defects, seasoning, member size, usage, etc. The property indicator values used are the 5% exclusion limit for strength properties, and the mean value for modulus of elasticity; these values are obtained through timber testing. Allowable design values are presented for approximately 30 species designations; Alaskan White Spruce data is not among these.

Several editions of the NDS are available; the two most recent editions, the 1986 and the 1991 editions were used herein as a basis for comparing allowable design values of other species against those obtained for Alaskan White Spruce. The two editions differ in the source of the test data used to formulate the design tables, and in the format used to present the data.

The 1986 edition of the NDS (26) is based on tests of small clear samples, and design tables presented in this edition contain entries for several grades of lumber in multiple sizes. Size categories are grouped by widths, and thus, for example, a different strength value is given for 4 inch lumber and for 5 inch lumber. The use of multiple grades, size groups, and grading rules may result in as many as 50 size/grade categories for a given species; this occasionally causes some confusion when reading the tables. This type of design data may be directly compared with the results obtained during this research project, as the data for the present study is obtained and presented in a manner similar to that used in the 1986 NDS.

The 1991 edition of the NDS (27) has reformatted the design tables incorporating two new main features. First, timber species which previously may have been graded under multiple grading agencies are now listed under a combined heading. Thus, the species has one set of design values, regardless of which rules are used to grade it. Second, the design tables no longer present design values for each size group of dimension lumber; instead, the NDS now uses a size correction factor which is applied to the table value to obtain the design value for a particular size of lumber. The NDS has always included a size factor, but in the past this factor applied only to lumber greater than 12 inches wide. Now this factor applies to all widths of lumber. In effect the 1991 NDS tables are standardized around 12 inch wide lumber; for smaller widths, the size factor is greater than 1, increasing the design value for smaller widths. Conversely, for lumber wider than 12 inches, the size factor is less than 1, reducing the allowable value. Comparisons between the 1986 NDS and the 1991 NDS design values, and the Alaskan White Spruce values developed here must include the size correction factor.

The 1991 NDS also incorporates new data based on testing of full size members with defects typical of each lumber grade into the design values. In some cases, this has resulted in reduction of the design values from the 1986 NDS, while in other cases the new data has resulted in an increase in the design values. This reflects changes in the quality of harvested timber due to such things as age at harvest and variation in the climate of currently harvested regions (i.e.

second growth versus old growth). The full size tests may also account for the presence of defects more accurately than the correction procedure used in the 1986 NDS. In theory, the 1991 NDS should contain an accurate representation of the allowable values for the listed species.

2.2 Timber Testing Procedures

Two American Society for Testing and Materials (ASTM) procedures are available for determining the mechanical properties and allowable design strengths of timber. These procedures differ in how the effects of knots and defects are handled during the development of the design values.

One procedure tests small, defect-free samples to determine the strength of the "pure" wood and relies on corrections of this value to account for defects in all sizes of members. This procedure is referred to as testing of "small, clear specimens", and was selected for use during this study.

The second procedure tests full size members of each lumber grade, complete with defects. This process is referred to as testing of "full size, in-grade" members. This obtains design values directly, but only for the specific sizes and grades tested.

Both procedures rely on the visual grading of lumber. Visual grading is accomplished by manual sorting of lumber into "grades" based upon visually observable defects such as knots, splits, shakes, checks, and wane. The strength associated with a particular grade is developed using the procedures described in either Section 2.2.1 or 2.2.2. The specific defects allowed in each grade are controlled by a set of "grading rules". Various agencies publish grading rules, which are certified by a national committee. Grading rules are discussed in Section 5.5.2.

2.2.1 ASTM D245 & D143: Testing of Small Clear Samples

American Society for Testing and Materials (ASTM) Document D245, titled "Standard Practice for Establishing Structural Grades and Related Properties for Visually Graded Lumber" (4) provides a method for determining the allowable structural properties of dimension and sawn lumber. The procedures given in D245 are the ones used during the project described herein.

Allowable design values are obtained using ASTM D245 in a three step process. First, minimum strength values must be developed for "pure" wood. This is clear, defect free wood typical of the tree species or group of species being investigated. Second, stress ratios are developed for each grade into which the lumber will be sorted using visual grading procedures. A stress ratio represents the difference in strength between a defect free member, and one containing actual defects. Finally, the allowable properties for a given grade of lumber are calculated as the product of the stress ratio and the clear wood strength property. The end result is tables of design values, such as those contained in the 1986 edition of the NDS, as described in Section 2.1.4 (26).

The clear wood minimum strength values are obtained using the testing procedures specified in ASTM D143, "Standard Methods of Testing Small Clear Specimens of Timber" (1). This document provides specifications for the selection, harvesting, processing, and testing of timber specimens for the purpose of obtaining strength properties for defect-free wood typical of the species being studied. This is accomplished using comparatively small test specimens which are cut from defect free portions of the sample trees. Several different types of tests are performed, ranging from bending to compression; the largest sample used measures 2 by 2 by 30 inches. Statistical analysis of the test results yields indicator values for the species as a whole. These indicator values are the average strength, and the 5% exclusion limits which represent a strength value at least 95% of encountered samples may be expected to possess. These values are modified by the stress ratios of D245 to produce design values for construction timbers.

Should more than one timber site or species be tested, the clear wood strength values from the various sampling sites may be combined together into a composite strength value for that clear wood combination using procedures given in ASTM Document D2555, "Standard Test Methods for Establishing Clear Wood Strength Values" (3). This document provides weighting procedures based upon the statistical variations in the densities and test results of the various species to develop formulations used to combine the separately tested sites or species. The procedure outlined in D2555 is only needed if values from more than one test site or species are to be considered.

The development of stress ratios is accomplished using formulas, definitions, and tables presented in D245, and may be performed for any combination of sizes and/or grades desired (4). Grades may be developed arbitrarily, however for general compatibility with the lumber industry and its markets, the selection of an existing, approved set of grading rules is recommended.

The tabulated strength values as published in engineering texts and design manuals are obtained by multiplying the clear wood strength values by the stress ratio for each grade. Values for any desired size or grade may be created in this manner.

2.2.2 ASTM D1990 & D198: In-Grade Testing

American Society for Testing and Materials Document D1990, entitled "Standard Practice for Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full Size Specimens" (6) provides an alternative to the test procedures given in D245 for developing the allowable properties of construction lumber.

Strength and stiffness properties developed using the procedures of D1990 are based upon tests of full-size members. Due to the variability encountered in full-size members, a relatively large number of pieces must be tested. Tests are performed on each combination of size and grade for which allowable properties are desired. Test specimens are typical of members that would be used in construction, and contain defects such as knots and splits to an extent typical of the particular grade of lumber being tested. Using statistical procedures, average values and 5% exclusion limits for the test results are developed. These 5% exclusion limits are then taken as the design values for the lumber grades. Since the tested samples contain defects representative of typical lumber, the test results require no further correction for defects or grading.

The testing of full size members is performed using practices contained in ASTM Document D198, "Standard Methods of Static Tests of Timbers in Structural Sizes" (2). Document D198 does not deal with selection or processing of specimens, but rather deals only with the procedures and apparatus needed to perform full size timber testing. Testing procedures described in D198 model real world testing situations, and in general resemble the procedures of D143 using apparatus suitable for testing full size members. Loading rates are also adjusted to reflect the larger timber sizes.

Should more than one sample site or species be tested, the results may be combined using the procedures given in ASTM Document D2555. Additional guidelines for combining the results of timber testing are provided in Document D1990.

The number of full size members to be tested is determined using guidelines presented in Document D1990. It is necessary to decide the number of timber sizes to be tested; this decision is based upon marketing and manufacturing considerations. Then, the number and types of lumber grades to be considered must be determined. This forms a testing matrix, with a cell for each combination of size and grade under consideration.

The number of tests to be performed for each cell depends upon the geographical area being tested. As a guideline, ASTM D1990 quotes a study of a "large" geographical area, in which 300 samples per cell were tested. The minimum allowable test matrix consists of three sizes and two grades, for a total of six test combinations, or 1800 full size members to be tested.

Once the tests have been completed, the mean and 5% exclusion limit values are calculated. At this point tables of allowable design properties may be developed for the sizes and grades tested to be used for design purposes. To a limited extent, design values for additional sizes and/or grades may be interpolated within the tested matrix, provided evidence of correlation can be provided. Extrapolation to grades or sizes outside the test matrix is not recommended.

2.3 ASTM D2915: Analysis of Data

Requirements for analysis of the collected data are found in ASTM Document D2915, titled "Standard Practice for Evaluating Allowable Properties for Grades of Structural Lumber" (5). The procedures outlined in D2915 may be used either to verify the quality of a lumber product with respect to an existing grading standard, or may be used to develop the indicator properties for a new lumber product. The indicator properties may then be used in conjunction with ASTM Document D245 and a set of grading rules to obtain the allowable design properties.

Indicator properties developed include the mean values and the 5% exclusion limits for the desired mechanical properties. These are developed using statistical techniques required by, but not specified or presented in ASTM D2915. Either parametric (probability distribution based) or non-parametric statistics may be used.

Document D2915 also provides formulas for correcting collected test data to standardized moisture content levels. Such correction is necessary before the statistical analysis of the data is performed, as the strength of wood varies with its moisture content. The moisture content correction procedure given in D2915 is based on seemingly empirical coefficients, and gives results similar to multipliers provided in ASTM Document D245. Additional procedures for moisture content correction are found in the <u>Wood Engineering Handbook</u> (17) and in references (14), (18), (20) and (36). The formulations given in these references rely on logarithmic equations created by fitting curves to test data, and appear to have a more scientific basis. Further discussion of moisture content correction is found in Section 5.2.3.

2.3.1 Statistical Procedures

ASTM D2915 requires at least one probability distribution be used in a parametric analysis, and that a goodness-of-fit test be completed on the selected distributions. Histograms are also required by ASTM D2915.

Three distributions are generally used in the statistical analysis of mechanical property data obtained from wood testing. These are the normal, log normal, and Weibull distributions. The suitability of each of these distributions to represent a given set of wood property data may be verified using a goodness-of-fit test such as the χ^2 test. The normal and log normal distributions are common probability distributions and are dealt with in many statistic texts (7,10,24). The Weibull distribution is a powerful, but less commonly used distribution (38). Development of histograms and the use of the χ^2 test may be found in any of the referenced texts.

The works of two groups of researchers were used as supplement references for statistical analysis. The first group, Goodman et. al., (12) published by the Electric Power Research Institute, provides a convenient presentation of the aforementioned statistical distributions in "Probability-Based Design of Wood Transmission Structures" (12). This reference is particularly useful in the application of the Weibull distribution. The second group of researchers, Sjaardema, et. al., (31) provides additional information on the Weibull distribution, and in particular provides formulations for approximating the parameters used in this distribution, as adapted from Peyrot and Aznavour (31).

2.3.2 Development of Allowable Design Properties

Recalling Section 2.2.1, ASTM D245 is used to develop stress ratios which are applied to clear wood strength values to account for the presence of defects in real world timbers. Applying the stress ratios to clear wood strength values results in the creation of allowable design properties.

While ASTM D245 may be used as a stand alone document through the development of arbitrary lumber grades, it is commonly used in conjunction with an existing set of lumber grading rules, preferably one which is approved by the lumber industry. This aids in the acceptance of the resulting design properties by industry and the engineering community.

The National Bureau of Standards, through the creation of a Voluntary Product Standard, PS 20-70, titled "American Softwood Lumber Standard" (25), has established the basis for lumber grading, grading inspection, grading certification, and quality control. This was accomplished by providing definitions of terms, and by the establishment of three committees. The first committee, the American Lumber Standards Committee (ALSC), is responsible for maintaining standards for lumber production. The second committee, the National Grading Rule Committee (NGRC), is responsible for creation of grading rules, strength ratios, and nomenclature. The final committee, the Board of Review, is elected by the ALSC, and is responsible for certifying grading rules submitted by industry, and the NGRC, prior to adoption by the ALSC. The committee members are selected in specified ratios from approximately 15 lumber manufacturing or inspection bureaus, and several offices of the federal government.

The various interactions of the committees produces sets of approved grading rules, of which several are available, including the Western Wood Products Association (WWPA) (41) and Northeastern Lumber Manufactures' Association (NELMA)(29).

NELMA and WWPA grading rules were used during this project for the creation of allowable design properties for several grades of Alaskan White Spruce. These two sets of grading rules are nearly identical to each other, and differ only in that WWPA includes provisions for larger lumber sizes than does NELMA. The rules provide detailed descriptions of each grading category, specifying the type and extent of defects allowed in each lumber grade. ASTM D245 is then used to determine the strength loss due to such defects.

CHAPTER 3: SAMPLE COLLECTION & PROCESSING

3.1 Introduction

Sample trees for this study were selected from Alaska State Timber Sale #NC 788 located near Birch Lake, Alaska, approximately two hours south of Fairbanks, Alaska on the Richardson Highway near mile 304. This sample site is within the Tanana Valley State Forest, and covers an area of 160 acres. The approximate location of the sample site is indicated by the map in Figure 3.1.

This sample site was selected for its proximity to Fairbanks, active lumber yards, and the University of Alaska, Fairbanks (U.A.F.) material testing facilities. Furthermore, Northland Lumber Company of Fairbanks was currently logging on the site. Northland Lumber was contracted to provide logging services, transportation, and initial milling of the sample trees.

The sample site is only accessible during the winter, as access to the site requires the crossing of several ice bridges. This required that enough trees to provide for complete testing of this sample site had to be selected and harvested together. The terrain of the sample site is typical of many Alaskan White Spruce stands in Interior Alaska: Boggy lowlands near rivers or ponds, carpeted with mosses, low brush, and common tundra-type vegetation, overlying silty/sandy soils.

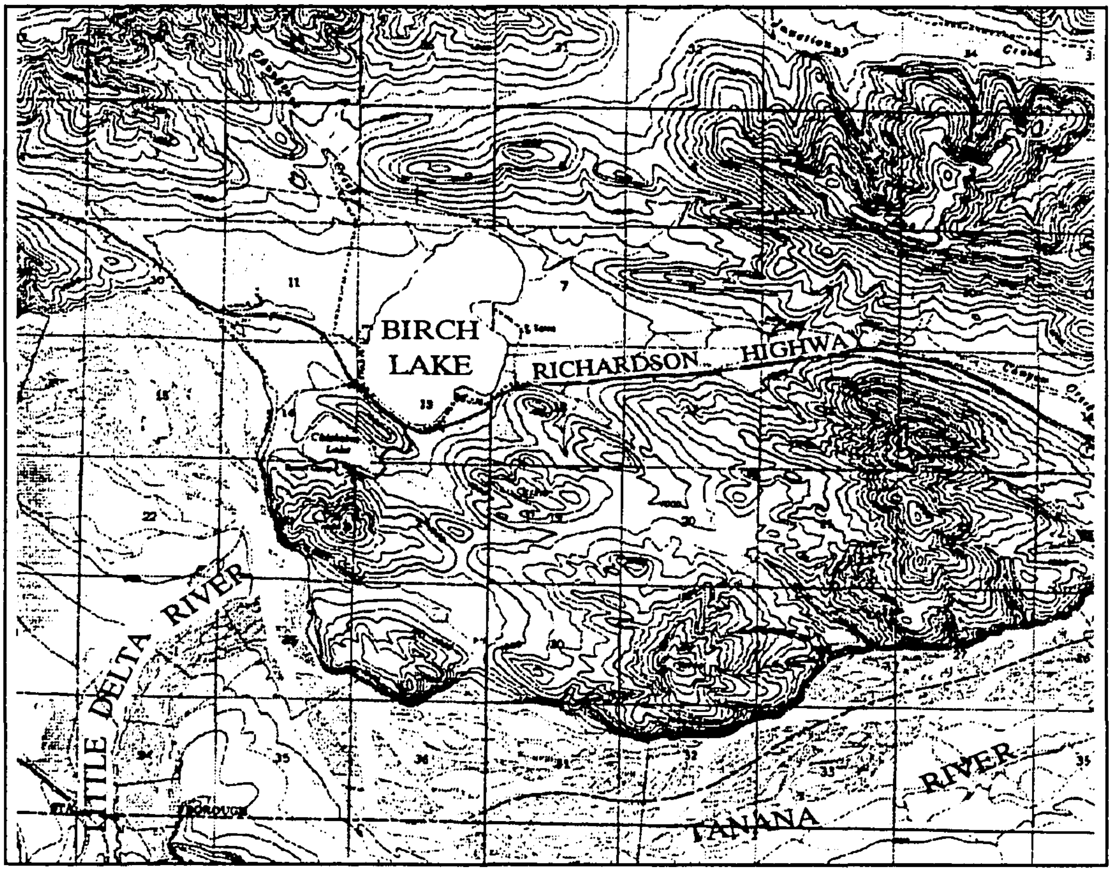

FIGURE 3.1: SAMPLE SITE MAP

3.2 Decision to Use ASTM D245 and D143

Several procedures are available for determining the allowable mechanical properties of wood species; two of these procedures are ASTM D245 discussed in Section 2.2.1 and ASTM D1990 which is discussed in Section 2.2.2. ASTM D245 involves the testing of small, clear specimens according to the guidelines of D143, while D1990 requires the testing of full size, in-grade members using the techniques described in D198. Prior to harvesting tree samples it was necessary to decide which procedure would be followed during the course of the research described herein.

The first factor considered in determining whether to use D245 or D1990 was that of available laboratory facilities. ASTM D245 required testing of relatively small, easily produced and handled test specimens, the largest being 2 by 2 by 30 inches. ASTM D1990 required the test of full size members as large as 2 by 12 inches by 8 feet long. Facilities to test the larger timbers were not immediately available, and the expense required to procure space and equipment would have been considerable.

The second factor concerned the number of trees needed for the two types of testing procedures. It was determined that ASTM D245, using the small clear samples would require between 12 and 30 small diameter trees to provide a total of about 1500 test specimens. ASTM D1990, using full size members would require approximately 110 trees of small diameter, based on the minimum test matrix of two grades and three sizes (2 x 4, 2 x 8 and 2 x 12 inches) with 300 samples per cell.

A third factor exists in the interpretation of the test results. Full size tests provide direct indication of the real world behavior, whereas tests of small clear samples must be corrected for defects prior to use. However, small clear test results could be used to develop design values for more sizes and grades of lumber and the in-grade testing procedures, without increasing the number of tests required.

In the end, it was decided to perform tests according to the procedures of ASTM D143, and develop design values using the ASTM Document D245. This the use of D245 and D143 allows for the use of existing facilities while collecting very useful data without the need for an excessive number of trees.

3.3 ASTM D 143 Requirements

3.3.1 Sample Selection

American Society for Testing and Materials (ASTM) Document D143 "Standard Methods of Testing Small Clear Specimens of Timber" (1) specifies that at least five trees representative of the species shall be selected from each test site. This sample size is based upon a nominal 24" diameter log; D143 requires that additional trees be collected should the available trees have smaller diameters. If smaller diameter trees are used, a number sufficient to ensure an equivalent number of test specimens must be selected. This number is arrived at using the ASTM specimen cutting diagram in Figure 3.2.

Each square in Figure 3.2 represents a 2 1/2 inch by 2 1/2 inch sample stick. Using these dimensions, and the pattern shown in the diagram, a 24 inch diameter tree yields 28 sample sticks per section, while a 12 inch tree yields only 12 such sticks. To obtain the number of test specimens that would be provided by five 24 inch trees, at least twelve 12 inch trees needed to be taken.

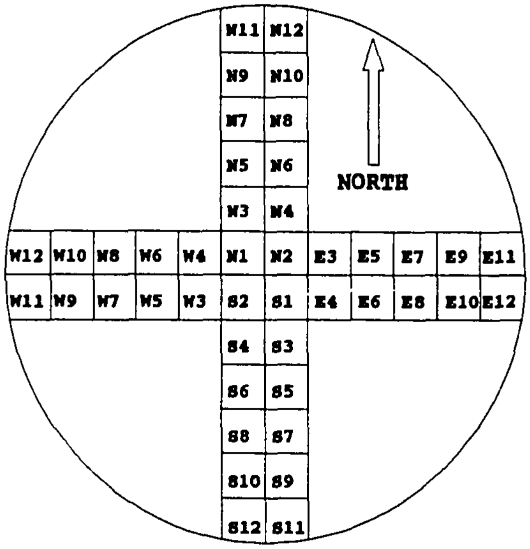

FIGURE 3.2: SAMPLE CUTTING DIAGRAM

Each 4 foot length of a tree or log after the butt swell is to be considered a "bolt". Bolts are designated by letters, beginning with "a" for the first 4 foot section above the stump, and continuing up the tree. Thus, the bolt letters indicate the position of the bolt with respect to the height of the tree.

Bolts c and d are to be collected from four of every five trees selected. The bolts to be collected from every fifth tree depend upon the height of that tree. Figure 3.3 shows the bolts to be selected from various heights of trees. Thus, should the merchantable bole of the fifth tree be 40 feet in length, bolts a, b, c, d, g, h, i, and j should be selected. This sampling scheme provides for testing wood from various heights within the trees, while concentrating the bulk of the testing on the larger diameter, more utilized, lower section of the tree.

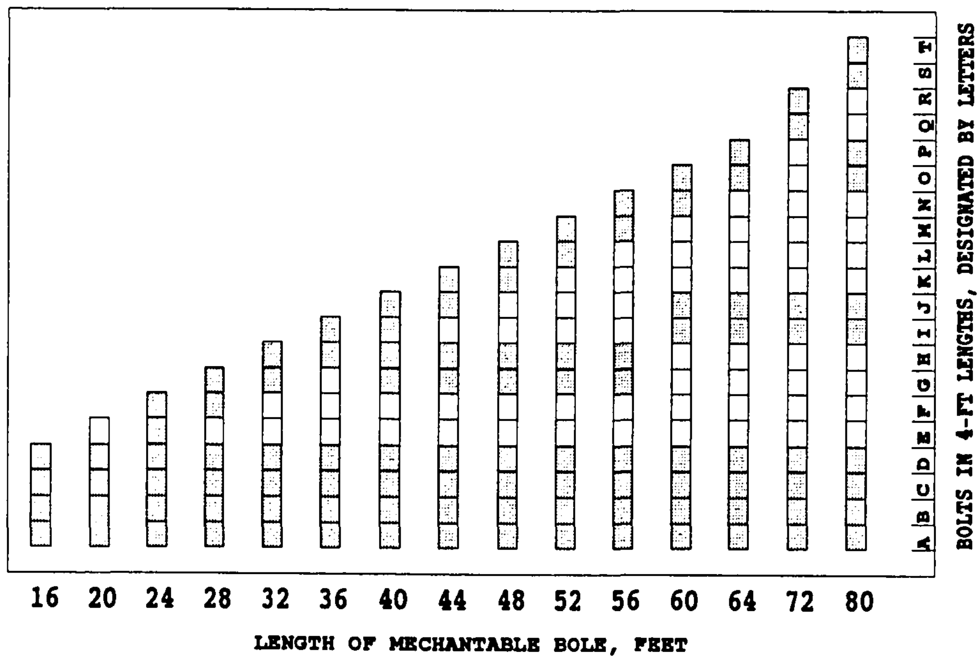

FIGURE 3.3: POSITION OF BOLTS TO BE COLLECTED

Trees typical of the sample location are to be chosen by an individual qualified to identify the species of the trees. ASTM requires that pertinent information about each tree be recorded, including the tree's species, diameter, and height. If necessary to ensure species identification, herbarium samples including leaves, twigs, fruit and bark should be obtained.

3.3.2 Sample Marking and Handling

Prior to the felling of the selected tree specimens, the tree number, and the north side of tree is to be plainly marked upon the trees. The tree number, the north side indicator, and the bolt designations are to be marked on the logs as they are cut from the felled trees, using the bolt lettering scheme described above and in Figure 3.3. Finally, all trees or logs shipped from a sample site shall be marked with a number unique to that shipment; this number is to be included in any invoices and will be used to reference the sampling location.

Throughout the shipping and storage of the logs or trees the bark will be left intact on each log, and care shall be taken to prevent damage to the logs. The ends of the logs shall be painted to lessen the effects of drying and end checking. Protection from checks, drying, decay, stains, or insect attack is to be provided, and the logs are to be processed before any damage may occur. Logs may be piled on skids clear of the ground and sprinkled with water, or alternatively may be stored in water prior to processing.

3.3.3 Specimen Cutting and Disposition

Prior to sawing the logs into specimen sticks, disks are to be cut from the ends of d bolts present in the sample. These disks are to be sealed to prevent drying, and will be used in shrinkage studies. The rest of the logs are to be marked and sawn into 2 1/2 by 2 1/2 inch square sticks, four feet long, using the pattern from Figure 3.2, where the letters N, E, S, and W indicate the cardinal compass directions.

ASTM D143 requires that the identity and location particulars of each specimen stick be traceable. To meet this requirement, each stick must be labeled with the shipment number, the tree number, the stick number, the bolt designation, and cardinal compass axis which applies to it. Thus a stick label of 1-23-W3D indicates the number 3 western stick from tree 23 of shipment number 1, in the "d" bolt.

Once sawn and marked, the specimen sticks are arranged into two separate groups, one group to be dried for seasoned wood tests, and the second group to be tested in the green condition. To provide test specimens for green and air-dry material that are closely matched, "composite bolts" are formed by interchanging half of the sticks of one bolt with half of the sticks from the adjacent bolt of the same tree. This forms two composite bolts, each containing equal portions of the two original bolts. One composite bolt shall be tested green, and the other shall be tested after seasoning.

To form the composite bolts, ASTM D143 provides the following selection table:

TABLE 3.1: COMPOSITE BOLT SELECTION TABLE

Composite Bolt to be Tested Green:					
Bolts a,c,e,g...	Sticks 1	4,5	8,9		12,13...
Bolts b,d,f,h...	Sticks 2,3	6,7	10,11		...
Composite Bolt to be Tested Seasoned:					
Bolts a,c,e,g...	Sticks 2,3	6,7	10,11		...
Bolts b,d,f,h...	Sticks 1	4,5	8,9		12,13...

Following this scheme, sticks a1, a4, a5, b2, b3, b6, c1, c4, c5, etc would be tested in a green condition, while sticks a2, a3, a6, a7, b1, b4, b5, c2, c3, c6, c7, would be tested in a seasoned condition, with an equal number of sticks from each compass direction included in each composite bolt. ASTM D143 provides a similar but slightly more involved explanation concerning the formation of composite bolts.

3.3.4 Sample Storage and Seasoning

The specimen sticks to be tested in the green condition are to be protected from drying by being closely piled and covered with damp sawdust, damp cloths or other similar means. As material is removed from storage for testing, it is to be cut to whatever size is required by the test procedure, covered with a damp cloth, and stored in a tightly closed container. Care is to be taken to minimize the storage of green material in any form. Testing of the green material should proceed as rapidly as possible to avoid damage due to rot or drying.

Specimen sticks selected for testing in a seasoned condition shall have the ends sealed by dipping them in melted paraffin. This serves to retard checking. The sticks shall then be stacked with wooden stickers (spacers) such as to permit at least 1/2 inch on each side of the sticks to allow circulation of air. The material is to have free air circulation, but is to be protected from sun, rain, snow, and contact with the ground. When the moisture content reaches a practical equilibrium, as indicated by nearly constant weight, the samples may be selected and tested. Seasoned sticks should be stored in a room having controlled temperature and humidity, with temperature in the range of 62° to 74° F, and humidity in the range of 64 to 66% R.H. For most species this environment will serve to condition the sticks to approximately 12% moisture content.

3.4 Actual Sample Collection Field Procedures

3.4.1 Field Trips

Two field trips to the Birch Lake sample site were made. The first trip served to provide logistical information about the sample site, while the sample trees were actually selected during the second trip. Both trips were made in early March, with clear weather, and with temperatures in the -30° F range.

After the first trip, it was apparent that enough trees of at least 12 inch diameter were available to meet testing requirements. Northland Lumber Company agreed to hand fell selected trees for the project, but cautioned that trees frequently split upon felling, due to impacts with other trees and the ground. With this in mind, and with regard to the requirements given in Section 3.3.1, it was decided to select 30 trees of 12 inch average bole diameter, as opposed to the twelve 12 inch trees required by ASTM. The extra trees allowed for a margin to ensure that adequate amounts of undamaged clear wood would be collected, and that no additional tree samples would be needed.

3.4.2 Sample Selection and Marking

George Sampson, a forestry research scientist with the U.S.D.A. Forest Service Pacific Northwest Experimental Station's Institute of Northern Forestry participated in the selection of the sample trees. George's experience with Alaskan tree species ensured that only Alaskan White Spruce trees were sampled.

Thirty trees typical of the stand were selected. Effort was taken to select trees that would yield good sample recovery; only straight, tall trees, without excessive taper were selected. Average diameter of the selected trees was approximately 14 inches, while average height was approximately 90 feet. Tree diameter at breast height (d.b.h.) was measured using a diameter reading tape. Tree height was measured using a clinometer. Diameters (d.b.h.) and heights of the sampled trees may be found in Table 3.2.

The north side of each tree was identified using a magnetic compass set to adjust for the magnetic declination of the area (28.5 degrees). The north side of the trees were then marked by cutting an approximately 4" wide by 5 foot long blaze in the tree bark using a draw knife.

Sample numbers were marked on the trees using spray paint. In addition to the paint marks, the tree number was carved into the blaze, and the carved number dyed with permanent felt marker. Orange flagging was tied to the trees to identify the selected trees to Northland's lumber crew, who felled the trees at a later date.

Northland's lumber crew felled the trees, and removed the branches. The trees were not cut into logs on-site, but rather were shipped to Northland's lumberyard for further processing in average lengths of approximately 54 feet, the length of a logging truck. As the sample collection procedure was conducted in the winter, it was possible to store the logs in a frozen state to minimize drying.

TABLE 3.2: DIAMETER AND HEIGHT OF SAMPLED TREES

TREE NUMBER	DIAMETER (Inch)	HEIGHT (Feet)		TREE NUMBER	DIAMETER (Inch)	HEIGHT (Feet)
1	15.4	97		16	15.1	96
2	12.5	82		17	12.1	80
3	11.6	84		18	13.2	81
4	13.2	90		19	13.8	99
5	16.7	89		20	14.9	91
6	12.8	81		21	14.5	104
7	14.2	87		22	13.7	90
8	14.4	81		23	11.7	91
9	17.0	82		24	13.7	95
10	13.3	84		25	12.5	92
11	15.2	83		26	11.9	86
12	12.8	87		27	12.7	87
13	14.3	80		28	13.9	84
14	12.8	92		29	14.7	86
15	14.8	94		30	13.6	81

3.5 Sample Processing

3.5.1 Rough Cutting of Samples

Cutting the sampled trees into specimen sticks was a multi-step process carried out in part at Northland's lumber mill in Fairbanks, and in part at the University of Alaska, Fairbanks' (U.A.F.) Physical Plant Woodshop.

The cutting procedure began at Northland's lumber yard by chain-sawing the trees into 17 foot lengths containing four 4-foot bolts as specified by ASTM, plus a six inch allowance on each end for some drying. As the trees were cut, each log was marked with the appropriate tree number, bolt designations, and north side indication. Labels were painted onto the tree trunks, and tags were stapled onto the butts of the logs.

Bolts were selected from the trees in accordance with ASTM D143 procedures. In general, the first 17 feet of each tree was sampled, after removing the butt swell and all obvious rot. In the larger trees wood from higher positions in the tree was taken whenever possible, in an effort to meet the ASTM requirement that high-wood be taken from at least one of every five trees. Rotten wood was counted in the lettering scheme even though it was discarded, thus maintaining the ASTM lettering convention. Depending on the amount of rot discarded before measuring the first 17 foot section, the first log formed either the ABCD, BCDE or CDEF bolts. Typical high-wood bolts taken were the EFGH, GHIJ and IJKL bolts. From the originally selected 30 trees, thirty-nine usable 17 foot logs were cut; these logs are listed in Table 3.3 Fifteen of these logs are low-wood, and 14 are considered high-wood. The low recovery rate is due to the presence of butt rot, rapid bole taper, and loss of three trees during felling or transport.

Six inch slabs were cut from the end of several logs containing "d" bolts for use in shrinkage tests; these slabs were labeled and sealed in plastic to prevent premature drying. A total of eight slabs were collected for the shrinkage studies.

A heavy coat of polyurethane paint was applied to the cut log faces to slow drying, and to distinguish the logs from the rest of Northland's lumber. The log pile was marked with a Forestry Department Experimental Forest sign. An inventory of the marked logs is given in Table 3.3.

TABLE 3.3 LOG AND BOLT RECOVERY SCHEDULE

TREE NUMBER	LOGS AVAILABLE	BOLTS RECOVERED		TREE NUMBER	LOGS AVAILABLE	BOLTS RECOVERED
1	ABCD EFGH	AB CD GH		16	ABCD	CD
2	ABCD	CD		17	CDEF GHIJ	CD GH IJ
3	Lost to Rot			18	Not Found	
4	BCDE	CD		19	ABCD	CD
5	CDEF GHIJ	CD GH IJ		20	ABCD EFGH IJKL	AB CD GH IJ KL
6	ABCD	CD		21	ABCD EFGH	AB CD GH
7	BCDE	CD		22	EFGH	GH
8	BCDE	CD		23	ABCD	CD
9	ABCD	CD		24	Not Found	
10	ABCD EFGH	AB CD GH		25	BCDE	CD
11	CDEF GHIJ	CD GH IJ		26	Not Found	
12	ABCD EFGH IJKL	AB CD GH IJ KL		27	ABCD EF	CD
13	ABCD	CD		28	ABCD EFGH	AB CD GH
14	BCDE	CD		29	BCDE	CD
15	ABCD EFGH	AB CD GH		30	BCDE	CD

Northland's lumber mill is not capable of producing the small width sticks used by ASTM D143 test procedures. Thus, it was decided to use the mill to rip the logs into six-inch, and ten-inch planks approximately 2 1/2 inches thick, and then re-saw these planks at the university's physical plant.

Due to the enclosed, semi-automated design of the lumber mill it was difficult to label planks as they were cut. In order to maintain the orientation and identity of the planks, color coding schemes were applied to the log ends. These color coding schemes are shown in Figure 3.4.

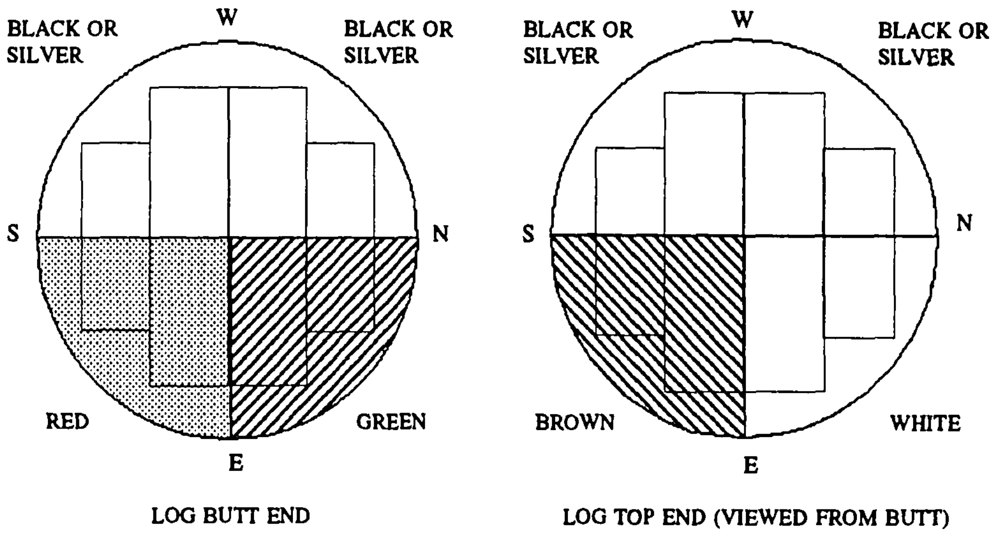

FIGURE 3.4: COLOR CODING SCHEME

The North and South quadrants on the East side of the log are painted different colors to distinguish the North and South sides of the log. The quadrants on the butt end of the log are of different colors than those on top of the log identifying that end as the butt. Furthermore, to provide a degree of separation between the different logs as they are cut, the western halves of the logs were painted in an alternating color pattern. This enabled the crew outside the mill to determine where the planks of one log ended, and those of a second log began as the planks came out of the mill on the green chain.

Notes regarding the size and sequence of the planks as they were cut were made by a crew member inside the lumber mill. The planks themselves were also sequentially numbered as they came out of the mill. Ninety-one planks were cut, with each log, in general, yielding a pair of six-inch and a pair of ten-inch planks. Through the use of the sequential numbers in combination with the cutting notes, planks could be recognized as coming from particular logs, at which point the color codes could be used to orient the cut planks properly. At this point the appropriate tree number and bolt letters were placed on the planks, which were then cut into eight foot lengths (each half with its own label). A total lineal footage of 1530 feet, or about 2400 board feet, was cut. Total sample weight was approximately 14,000 lbs.

The planks were loaded into a truck for transport to the U.A.F. physical plant. Due to the time of the week it was necessary to store the planks over the weekend. The planks were sprinkled with water and covered with a plastic tarp for storage at the U.A.F. experimental farm.

3.5.2 University of Alaska, Fairbanks, Physical Plant

Re-sawing of the cut planks into specimen sticks was conducted at the U.A.F. Physical Plant Woodshop. This facility provided temporary storage and layout areas, in addition to a large (20 foot blade, 48" throat) industrial bandsaw used to rip the 2.5" X 6" and 2.5" X 10" planks into the specimen sticks.

The eight foot long planks were first cut into 2 1/2" by 2 1/2" by eight foot long strips. These strips were laid out in the order they were cut, in small groups corresponding to the plank they were cut from; this was done to maintain the identity of the individual planks.

At this point, using the color codes and the bolt letters previously marked upon the planks, the final specimen number consisting of shipment number, tree number, bolt letter, compass direction, and stick position number could be marked upon each stick. The eight foot strips were then cut into the required four foot sticks (each with its own unique stick number).

The labeling was performed using a labeling diagram based on the color coding scheme shown in Figure 3.4. This labeling diagram is shown in Figure 3.5. As can be seen from the diagram, once the color code on the stick has been matched with the codes in Figure 3.5, the stick label consists of the tree and bolt designations plus the stick letters on the diagram. This method of keeping track of the stick identities proved to be very effective and reasonably practical.

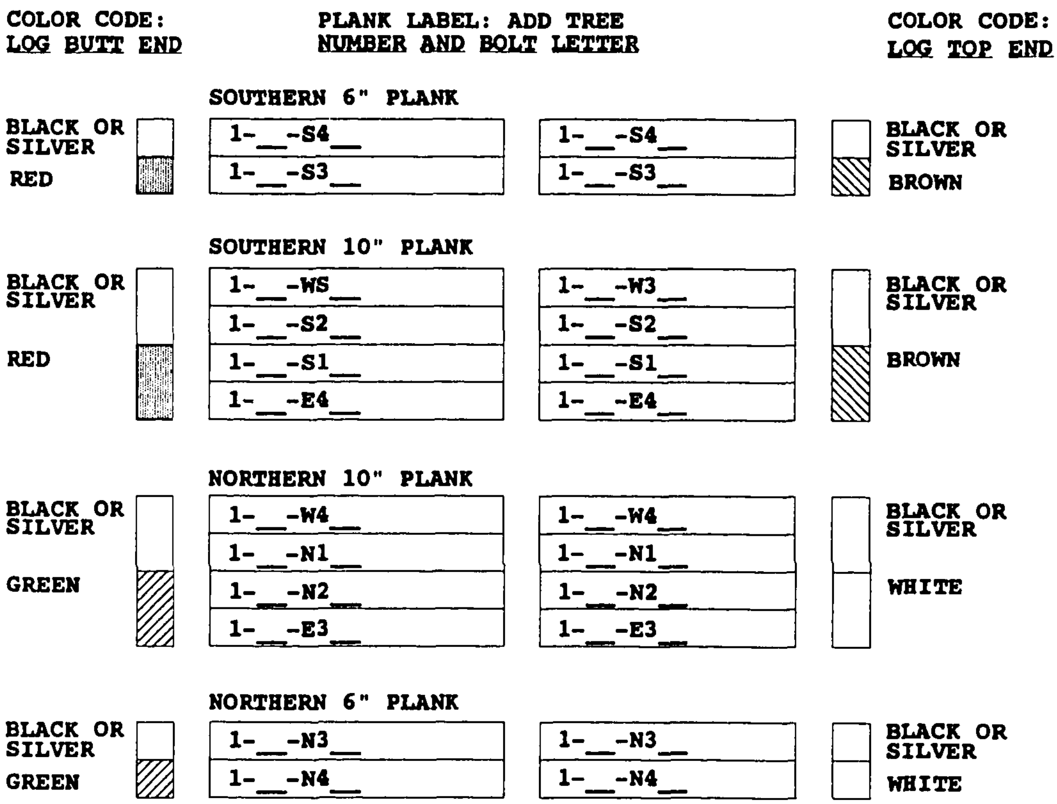

FIGURE 3.5: SAMPLE LABELING SCHEME

3.5.3 Composite Bolts, Seasoning and Storage

Composite bolts consisting of alternating sticks from adjacent bolts were formed in accordance with ASTM D143 using the procedure outlined in that document and as summarized in Section 3.3.3 above. Four pallets of test samples, measuring roughly four feet square by three feet high were created.

The wood to be tested green was transported to a concrete curing room within the materials test facility. This room maintains a 100+% condensing, highly humid environment. To protect the wood from molds, the samples were sprayed with a common household disinfectant. The samples were covered with a tarp to protect them from direct exposure to water. Moisture content studies done with an electronic moisture meter and oven dried samples indicate a very slow increase in moisture content within this environment. Thus, the concrete curing room is a good facility for storing green lumber. However, this environment is well suited to mold and fungal growth; molds form on some wood surfaces almost immediately in the curing room, but no structural damage is evident for some time. However, molds and fungus, and possibly other forms of rot do become a problem after several weeks of storage.

The wood to be tested in a seasoned condition was piled on pallets with the layers separated by stickers. The samples were banded together to provide restraint during drying to minimize warping, and transported to the test facility. After several weeks of air drying, the samples were covered with a tarp and equipped with a humidistat controlled humidifier to maintain the humidity at approximately 70 % R.H. Sample moisture contents at the time of testing were 12% plus or minus 2.5%. Individual moisture contents were taken on each test sample, at the time of the test.

3.6 Laboratory Procedures

Throughout the course of the testing procedures, test specimens would be withdrawn from the storage facilities for cutting into test specimens. The cutting of the test specimens was performed at either the U.A.F. Physical Plant Woodshop when a table saw was required, or at the School of Engineering Machine Shop when a small bandsaw or drill press was required. Specific cutting procedures are described in detail in Chapter 4.

Whenever it was necessary to remove specimens from storage for processing into test specimens, reasonable measures were taken to protect the wood from moisture content changes. This was accomplished primarily by transporting the samples in air-tight plastic or metal storage containers, covering the green wood with damp rags, and limiting the exposure of the specimens to uncontrolled environments. Portions of specimen sticks that remained after cutting the needed test specimens were relabeled and returned to storage.

CHAPTER 4: TESTING EQUIPMENT AND PROCEDURES

4.1 Introduction

ASTM D143, "Standard Method of Testing Small Clear Specimens of Timber" specifies equipment and testing procedures for thirteen mechanical property tests. Eleven of the thirteen tests were used during this project, including the following: Static Bending, Compression Parallel to Grain, Compression Perpendicular to Grain, Hardness, Shear Parallel to Grain, Cleavage, Tension Parallel to Grain, Tension Perpendicular to Grain, Nail Withdrawal, Specific Gravity and Shrinkage in Volume, and Radial and Tangential Shrinkage (1). A description of the equipment and procedure required by ASTM for each of these tests follows.

The two tests not conducted during this project are the Impact Bending test, and the Toughness test. The impact bending test is a work-to-failure test in which a load is dropped from progressively greater heights until the sample reaches six inches of permanent deflection. This test result is not typically employed in engineering design.

The toughness test is similar in nature to a Charpy test. In the Charpy test, a heavy pendulum is swung into a small sample, fracturing it. However, the toughness test for wood requires a much more complex apparatus. Test results from the toughness test are not commonly used in engineering design. Neither of these two tests is commonly performed, nor are test results widely available (17).

A primary objective of the research was to obtain high accuracy test results, while automating the testing program as much as possible within the guidelines of ASTM D143. To accomplish this, computer controlled data collection equipment, electronic measurement transducers, and semiautomatic testing equipment were utilized during testing. The testing system developed is unlike older styles of timber testing equipment which rely on manually operated loading machines and dial gauges that must be read by an operator. Such a system can be difficult to use, time consuming, and provides numerous opportunities for error. In contrast, the testing system presented here is largely automatic, requiring only that the operator load the sample, and then start the test. Data is collected automatically, and stored within a computer system. This same computer system reduces and analyzes the test results, reducing the possibility of error. The end result is accurate, precise test results.

4.2 MTS Testing Equipment

Semi-automated load frame equipment and control units manufactured by MTS Corporation were used extensively during the course of the testing procedures. MTS load frames and controls possess a high degree of accuracy and precision. This helps to deliver consistent, repeatable test results. The test frame used for this work has a capacity of 55,000 pounds (55 kips) and a useable hydraulic ram travel of 5 inches.

The testing equipment consists of a hydraulically powered #810 Series load frame equipped with load and displacement transducers, and a #458.20 Microconsole feedback control unit. The feedback control unit performs two main functions. First, the unit conditions the voltage signals of the electronic transducers to allow these values to be read directly as load and displacement. Second, the control unit uses a closed-loop feedback system to constantly adjust the operation of the load frame. This allows the operator to select the precise amount of load or displacement the loading ram will undergo. The load or displacement may be set to vary with time in the shape of any waveform desired or with sample response or with respect to some external input.

All load tests conducted during this project were performed using a constant displacement rate of the loading ram as required by ASTM D143. This displacement was generated using an MTS Corporation #458.91 Microprofiler digital signal generator in conjunction with the #458.20 Microconsole. This signal generator possesses an output resolution of 18 bits when generating the slow displacement ramp rates used in this study. This corresponds to about 5 digit accuracy, or .002% of the signal generator's full scale output. Various ramp rates are used for the different tests. The rates are given with the descriptions of the tests below.

The accuracy and precision of the applied load or displacement pattern depends upon the transducers to which the feedback control system is attached. As the tests were conducted in a displacement controlled mode, the transducer in question is the LVDT (linear-variable-displacement-transformer) contained inside the MTS loading frame's hydraulic ram.

Different "ranges" may be selected for this LVDT, depending upon the amount of displacement travel needed; the smaller the range used, the higher the transducer resolution. Two ranges were used during testing; a ±5 inch range used for the static bending tests, and a ±1 inch range for all other tests. The maximum displacement error present in the transducer is .3% for the ±1 inch range and .4% for the ±5 inch range. Actual testing procedures result in somewhat better performance, as the errors given above represent the extreme values of the transducer calibration curves. The accuracy of the transducers used to collect load and deflection data during the test procedures varies from test to test, and will be dealt with in Section 4.3, and in the sections describing the individual tests.

4.3 Data Collection Procedures

The automated electronic data collection system used for this test procedure consists of an Intel 80486 based computer equipped with an analog-to-digital converter (ADC) board, connected to the #458.20 Microconsole and whatever transducers the test procedure may require. Computer programs running on the computer control the data collection process, and analyze the collected data.

4.3.1 Transducers

Transducers used for this project include: strain-gauge based load cells, linear-variable-displacement-transformers (LVDTs), and strain-gauge based clip-on extensometers. The specific instrumentation used for each test is listed below with the individual test descriptions.

Load cells generally use a steel element with strain-gauges bonded to it. Extension or compression of the steel element distorts the strain-gauges, resulting in a change in gauge resistance. The resistance change may be related to strain, and then further related to stress and load through constitutive modeling. Load cells are used in all of the mechanical properties tests presented here. A quality load cell will have high accuracy and precision.

LVDTs are displacement measuring transducers which use three transformer coils, and a movable core which provides magnetic coupling between the coils. Moving the core from the center position unbalances the transformer, and creates a voltage which may be interpreted as a displacement. LVDTs are used in the mechanical tests which require the measurement of relatively large displacements. Error in LVDTs is commonly described in terms of linearity, which is the amount an LVDT's output deviates from a linear calibration curve. This value varies from .1 to 5%, although higher accuracy and precision may be obtained by use of polynomial calibration curves.

Strain-gauge based extensometers consist of a pair of arms connected by a flexible strain-gauge element. Changing the distance between the arms bends the strain-gauge. This results in a resistance change which may be related to displacement via a calibration curve. Extensometers are used in the mechanical tests which require the measurement of small displacements, and are typically attached to test specimens using rubber bands or screws. Extensometers generally have high inherent accuracy, and may be calibrated for high precision.

Power supply, and signal conditioning for the transducers is provided by the MTS Microconsole control system, and by an additional external power supply. The MTS system amplifies the transducer signals, and provides a digital LED display of the outputs. The transducers may provide control input to the MTS system as described in Section 4.2. All of the mechanical tests performed here utilize an LVDT attached to the hydraulic loading ram for control feedback.

4.3.2 Analog-to-Digital Convertor

All of the transducers listed in Section 4.3.1 generate a voltage output. This voltage must be converted into a numeric form in order to allow storage and manipulation of the data. This conversion is accomplished by an analog-to-digital convertor (ADC). This device functions as a very precise, high speed voltmeter, measuring the transducer output voltages, and returning digital values to be stored in computer memory.

The ADC used here is capable of simultaneous data acquisition on 8 channels at a rate of up to 16kHz. The ADC has a 16 bit resolution for an accuracy of about 0.02%. Most of the tests presented here use data sampling rates of 1 hz, although tests with small event windows are sampled at 5 hz. Either sampling rate is higher than is attained when using manual data collection by at least an order of magnitude. This results in smoother data plots and more accurate test results.

4.3.3 Computer System and Control Programs

Data storage and processing is performed using an Intel-80486 based PC type computer. This computer houses the ADC unit described in Section 4.3.2, and performs several functions.

Testing procedures are performed and controlled by software programs run on the computer. These programs provide for interactive input of pertinent test data such as sample number, sample dimensions, weight, ambient temperature, and other data. Examples of the types of input data may be seen in the example test reports provided in Appendix A. After accepting the input data, the computer proceeds to initialize the ADC board, and programs the MTS Microprofiler signal generator. At this point control returns to the operator, who is prompted to load the sample. Once the sample is loaded, a trigger button on the MTS console synchronizes the computer, the ADC board, and the MTS controllers, and the test begins.

During the test, the ADC board collects test measurements from the various transducers. This data is stored in computer memory, and displayed on the monitor. Calibration equations within the individual testing programs are used to convert the numeric voltage data collected by the ADC into load and displacement data with engineering units. At the end of the test, a summary of the test results are displayed, and data is stored to the hard disk. Sample data files are provided in Appendix A.

Comprehensive data analysis is performed at a later date using computer spreadsheet software. The spreadsheets are used to plot the data, and to perform analysis for such items as maximum loads, stresses, strength, and modulus of elasticity. Linear-regression algorithms within the spreadsheets are used to create best-fit lines for the linear portions of loading curves. The results of the regression analysis are used to determine the proportional limit. Finally, the spreadsheet prints out a test report in a form satisfying ASTM D143 requirements. Sample reports are available in Appendix A. Additional discussion of the data analysis procedures is presented in Chapter 5 of this report.

4.4 Mechanical Properties Testing Apparatus and Methods

4.4.1 Static Bending Test

The static bending test consists of loading a simply supported beam at its midpoint. The load is increased until the beam fails. This test may be used to determine the modulus of rupture (MOR) which is the ultimate bending strength and the modulus of elasticity (MOE) which is a measure of stiffness of the sample being tested.

4.4.1.1 ASTM Requirements

ASTM D143 provides specifications for the static bending test, along with requirements on the number and type of test specimens needed (1). The static bending test is conducted using nominal 2 by 2 by 30 inch specimens, with the actual height, width and length being measured prior to testing. Samples may contain defects such as knots, provided the defects will not influence the failure of the sample. In general, this means that no defects are allowed in the middle third of the test specimen.

The sample is to be supported on knife edges over a clear span of 28 inches. The knife edges are to be mounted on rollers which are free to move as the sample bends.

Load is applied to the center of the sample through a curved Maple bearing block. The specimen is to be placed such that the load is applied through the bearing block to the tangential surface nearest the pith. Load is to be applied by constant displacement of the loading block at a rate of .10 inch per minute.

Load-deflection measurements are to be taken until the maximum load is reached for each test, and until failure for at least one-third of the tests. Failure is defined as the point at which the sample has either attained six inches of deflection, or fails to support 200 pounds of load. Failure patterns are to be described according to the appearance of the failure surfaces. Typical failure patterns are shown in Figure 4.1. Also, immediately after the test, a section one-inch long is to be cut from the failed specimen for subsequent moisture content determinations.

Deflections are to be determined using points on the neutral plane of the bending specimen; this plane is located at mid-depth of the beam and does not change in length as the beam bends. Deflections are to be measured between the neutral plane at center span and a line passing through the neutral plane at the supports (see Figure 4.2). Deflections are to be read to the nearest .001 inch for loads below the proportional limit, and then to the nearest .01 inch after exceeding the proportional limit.

At least one static bending test is to be conducted from every two sticks, with random selection. Thus, half of the green wood, and half of the seasoned wood is to be tested in flexure. For a sample site of five 24" diameter trees this results in approximately 100 tests for each of the two seasoning state.

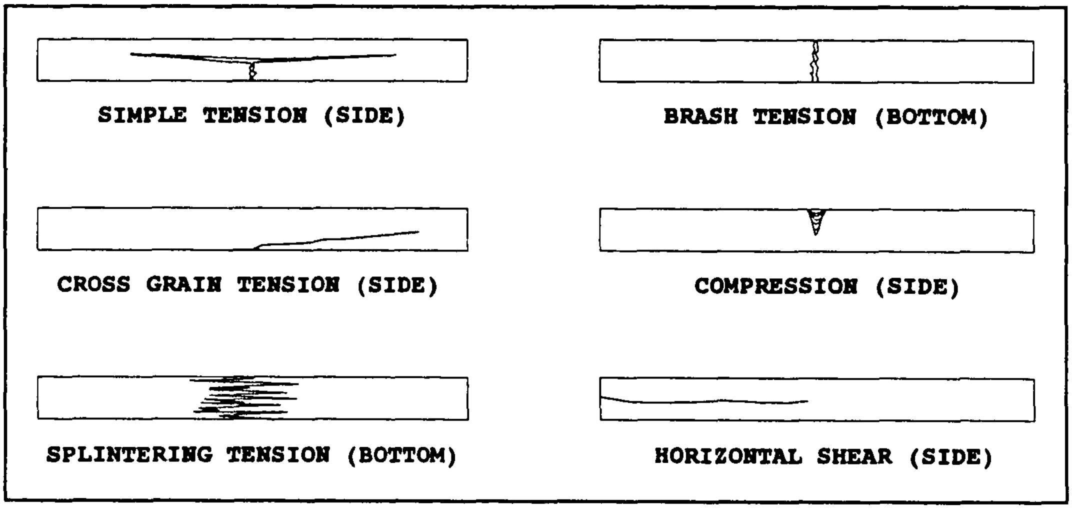

FIGURE 4.1: BEAM FAILURE PATTERNS

4.4.1.2 Static Bending Apparatus

To conduct the static bending test, a "beam table" which can be mounted on an MTS loading frame was fabricated. This beam table was designed and constructed to meet minimum ASTM testing requirements, while incorporating automatic, electronic data collection features. A sketch of the flexural apparatus is shown in Figure 4.2.

The base of the beam apparatus consists of square structural tubing which mounts to the MTS loading ram via a flange. This tube is equipped with riser blocks which provide the clearance needed for the deflected timber specimen.

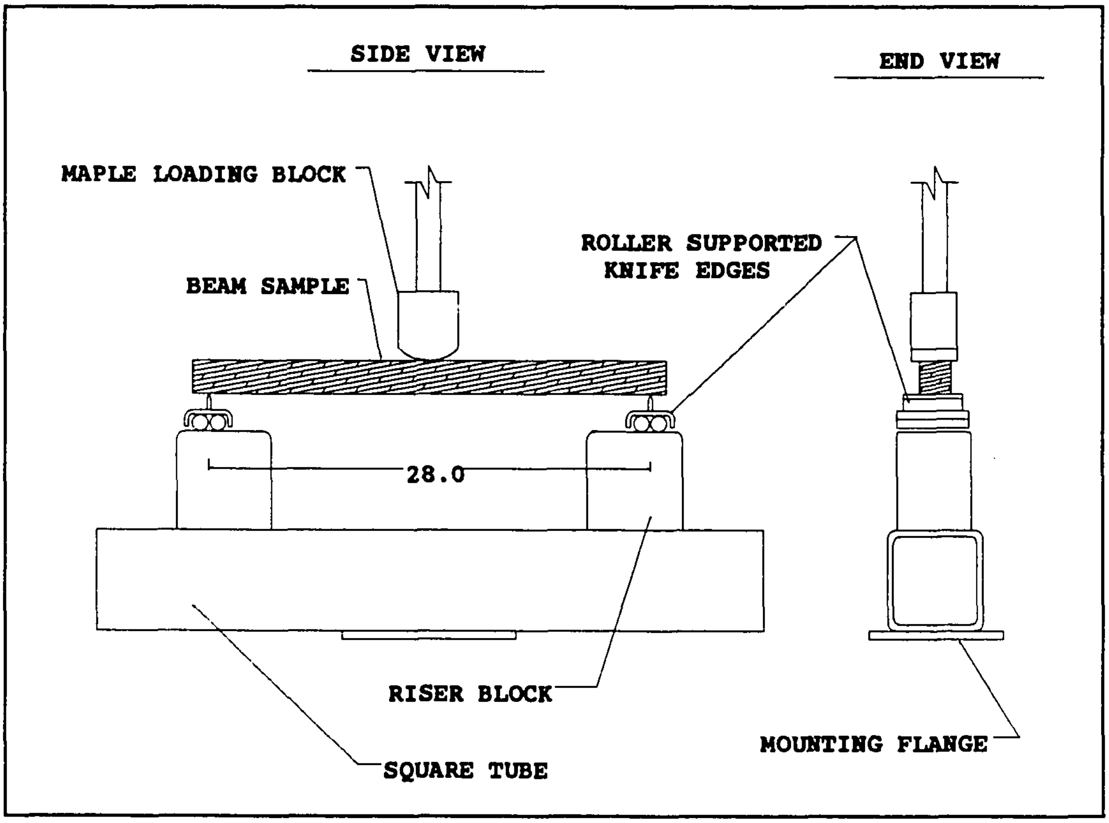

FIGURE 4.2: STATIC BEAM APPARATUS

Knife-edged roller assemblies with hardened rollers sit atop the riser blocks. These knife edges support the sample. The knife edges are sharp, and will cut into the sample to relieve normal and torsional stresses should the sample twist during testing. The span length of 28 inches is set using a gauge bar with notches which slip over the knife edges. This same gauge bar centers the roller blocks on the apparatus.

Load is applied through a Maple bearing block cut with curvatures specified in ASTM D143. This block is supported by a one inch hardened steel shaft connected to a load cell transducer. The load is generated by raising the beam table, and thus the specimen, against the bearing block which remains stationary.

Deflection of the bending specimen is measured by means of the deflection yoke shown in Figure 4.3. This yoke rides on the loading shaft by means of a linear ball bearing assembly and a ball bearing pivot. These bearings allow the yoke to swivel, pivot and travel up and down. The lower edge of the yoke rides on two bearing pins attached to the neutral axis of the bending specimen by means of clamps with needle pointed thumb screws. Thus, as the sample is raised during the loading process, the deflection yoke may follow every move of the neutral axis, including movements caused by the sample settling on the knife edges. Deflection at the midpoint of the specimen is measured with an LVDT, whose measuring prod bears against a metal bracket fastened to the sample's neutral axis with a small tack.

As the test is conducted, the timber sample rises against the loading block and is forced to bend. As this happens, the deflection yoke raises along with the sample, maintaining a constant distance between the LVDT body and the neutral axis due to the bearing pins clamped on the sample. As the specimen deflects in the middle, the LVDT prod riding on the center bracket follows the deflection of the beam, allowing the deflection to be registered and recorded.

The load cell used for this test has a maximum capacity of 5000 lbs, with a maximum error of .018% within typical testing limits using a simple linear calibration equation.

The LVDT used has a total possible travel of 4 inches, with a linearity of .13%. The use of a polynomial calibration equation allows an accuracy of .0002 inch, or roughly .1% within the proportional limit of the test. This is considerably better than that attainable with a dial gauge. The MTS loading frame is used in a ±5 inch travel range for this test.

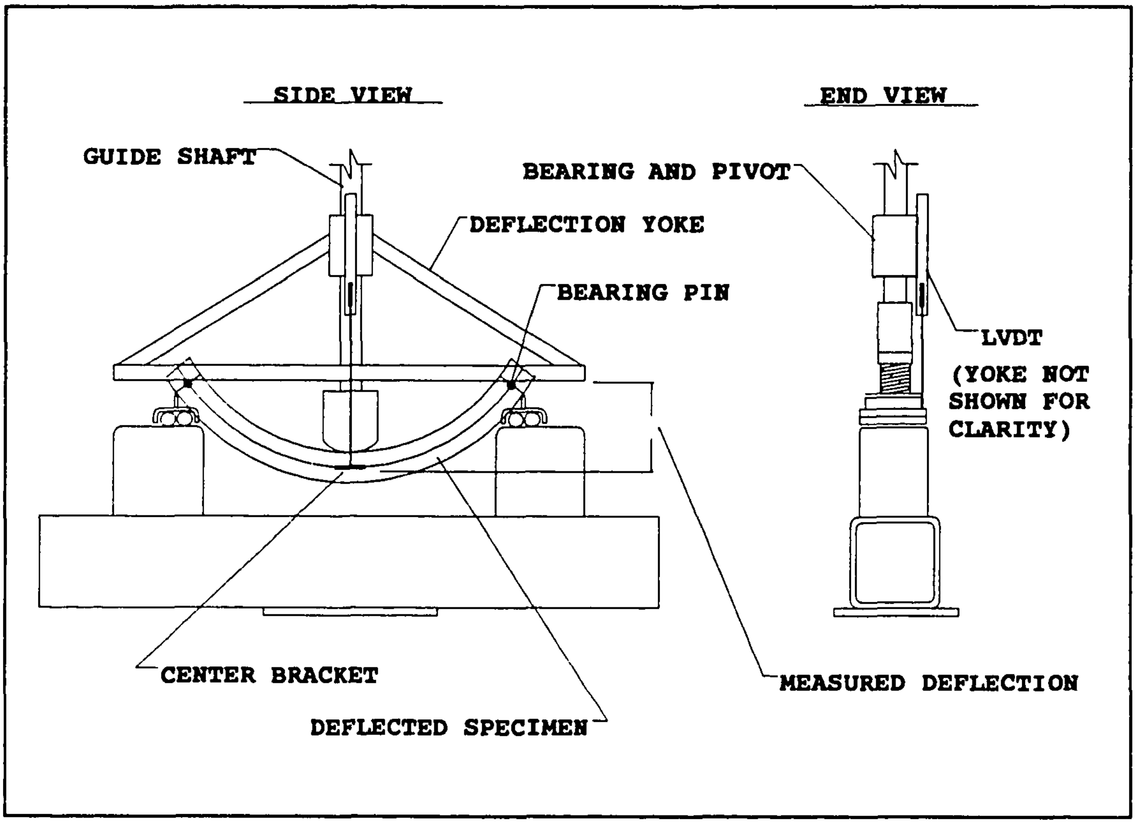

FIGURE 4.3: DEFLECTION YOKE

4.4.1.3 Static Bending Test Procedures

Samples are prepared for the static bending test by table sawing all four sides of the specimen sticks described in Section 3.4 such that fairly smooth surfaces are obtained, and such that the specimen has the overall dimensions specified in D143. Prior to testing, specimens are stored in a plastic box with fitted lid to prevent excessive changes in moisture content.

As a sample is removed from the storage box for testing, the cross sectional dimensions are measured using digital calipers to the nearest .001 inch. Length is measured with a tape measure. While the length is being measured, the loading span of 28 inches is marked on the specimen, along with the midpoint and centerline of the sample. The sample weight is measured using a digital balance to the nearest .1 gram.

The specimen identification and dimensions are entered into the computer program, and the testing equipment prepared for sample loading by centering the knife edges with the gauge bar and by raising the deflection yoke to facilitate sample loading. The neutral axis clamps are attached to the specimen and the center bracket is attached by means of a tack. The specimen is placed on the knife edges and centered under the loading head, with the tangential surface closest to the pith facing upward. A preload of 10±5 pounds is applied to restrain the specimen, and the loading yoke is lowered onto the neutral axis clamps with the LVDT prod bearing on the center bracket.

The test is initiated at a constant displacement rate of .1 inch per minute, with the data collection equipment sampling the time, load, specimen deflection, and displacement of the beam table at a rate of once per second. This continues until the failure criteria given in Section 4.4.1.1 are meet, at which point the test is stopped, and the data stored to hard disk.

The specimen is removed from the apparatus, and notes are made describing the failure mode. A moisture content cube is removed from near the failure site, and sealed in a metal can.

A total of 197 samples were tested in the green condition. 131 of these samples were inadvertently tested at a loading rate of .2 inches per minute. However, on comparison with results from the test of 66 green samples at the prescribed loading rate of .1 inches per minute no real changes in the results were apparent; this is attributed to the green wood not being very rate dependant at low strain rates. 136 samples were tested in the seasoned condition at the correct loading rate. Data from these tests is presented in Appendix B. Analysis of the collected data will be dealt with in Chapter 5.

4.4.2 Compression Parallel to Grain Test

The compression parallel to grain test consists of loading a short timber column in compression, with the grain running parallel to the direction of the applied load. The load is increased until the sample fails. This test may be used to determine modulus of elasticity and compressive strength for timber.

4.4.2.1 ASTM Requirements

ASTM D143 provides specifications for the compression parallel to grain test, along with requirements on the number and type of test specimens needed (1). The parallel compression test is conducted using 2 by 2 by 8 inch nominal specimens. The minimum cross sectional dimensions and the overall length are to be measured prior to testing. Any defects must be very small to avoid influencing the failure of the sample. The ends of the specimen are to be as parallel as practical, and cut cleanly to allow a determination of the growth ring spacing and summerwood content.

The sample is to be tested between compression platens in a loading frame. The upper compression platen must be mounted on a spherical bearing. This compensates for a lack of parallelism in the sample ends. Load is applied at a continuous rate of .003 inches per minute per inch of sample length. This is .024 inches per minute for an 8 inch specimen. Loading stops after the sample has failed, as indicated by the load peaking.

Load versus deflection measurements are to be taken over a gauge length not to exceed 6 inches in order to avoid end effects. The readings are continued for some time after the proportional limit has been reached. Deformations are read to the nearest .0001 inches.

Failure patterns are described according to the appearance of the specimen after testing. Typical compressive failure patterns are shown in Figure 4.4. Immediately after the test, a one-inch long section is to be cut from the specimen for moisture content determination.

A special consideration with the parallel compression test is that the failure develop within the main body of the specimen and not at the very ends. If test specimens tend to fail at the ends, ASTM suggests that the moisture content of the sample ends be lowered to raise their strength. With green specimens, this may be accomplished by covering the middle of the specimens with damp cloths and allowing the ends to dry. Dry specimens may be conditioned in a similar manner, using a desiccator to dry the ends of the samples.

One compression parallel to grain test is to be conducted on each stick. For a normal sample site of five 24" trees, this results in roughly 200 tests in each of the green and seasoned states.

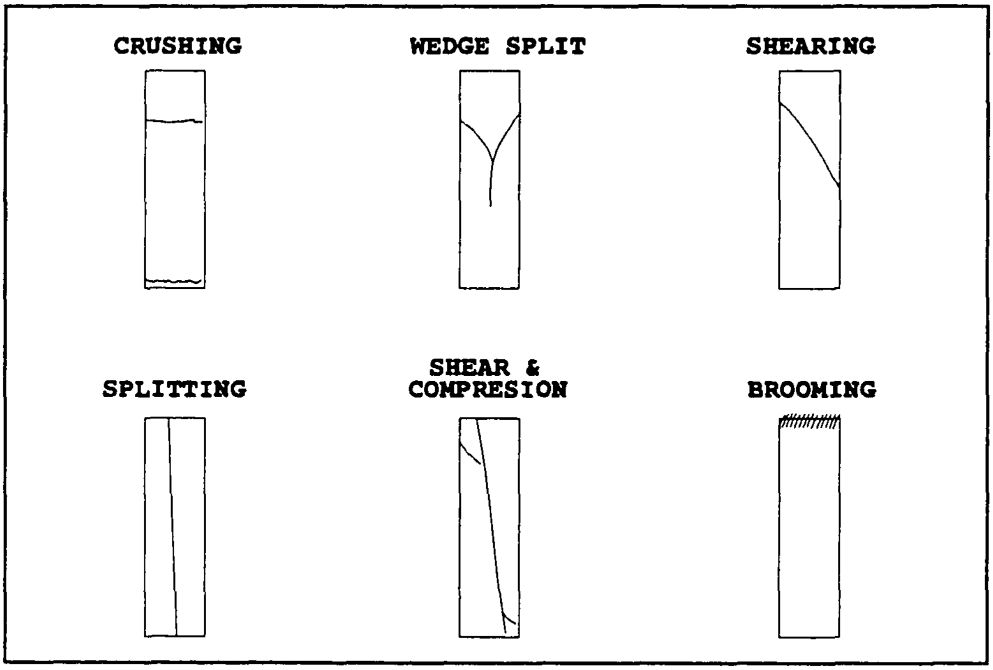

FIGURE 4.4: SHORT COLUMN FAILURES

4.4.2.2 Compression Parallel to Grain Apparatus

It was necessary to purchase or construct a compressometer for measuring the change in length of the sample during compressive loading. Review of commercially available devices made it apparent that a custom fabricated device would best suit the task, and allow incorporation of electronic data collection equipment. Thus, the compressometer shown in Figure 4.5 was built.

The compressometer consists of two clamps which are securely fastened to the test specimen with needle point thumb-screws. The lower clamp assembly serves as a mount for

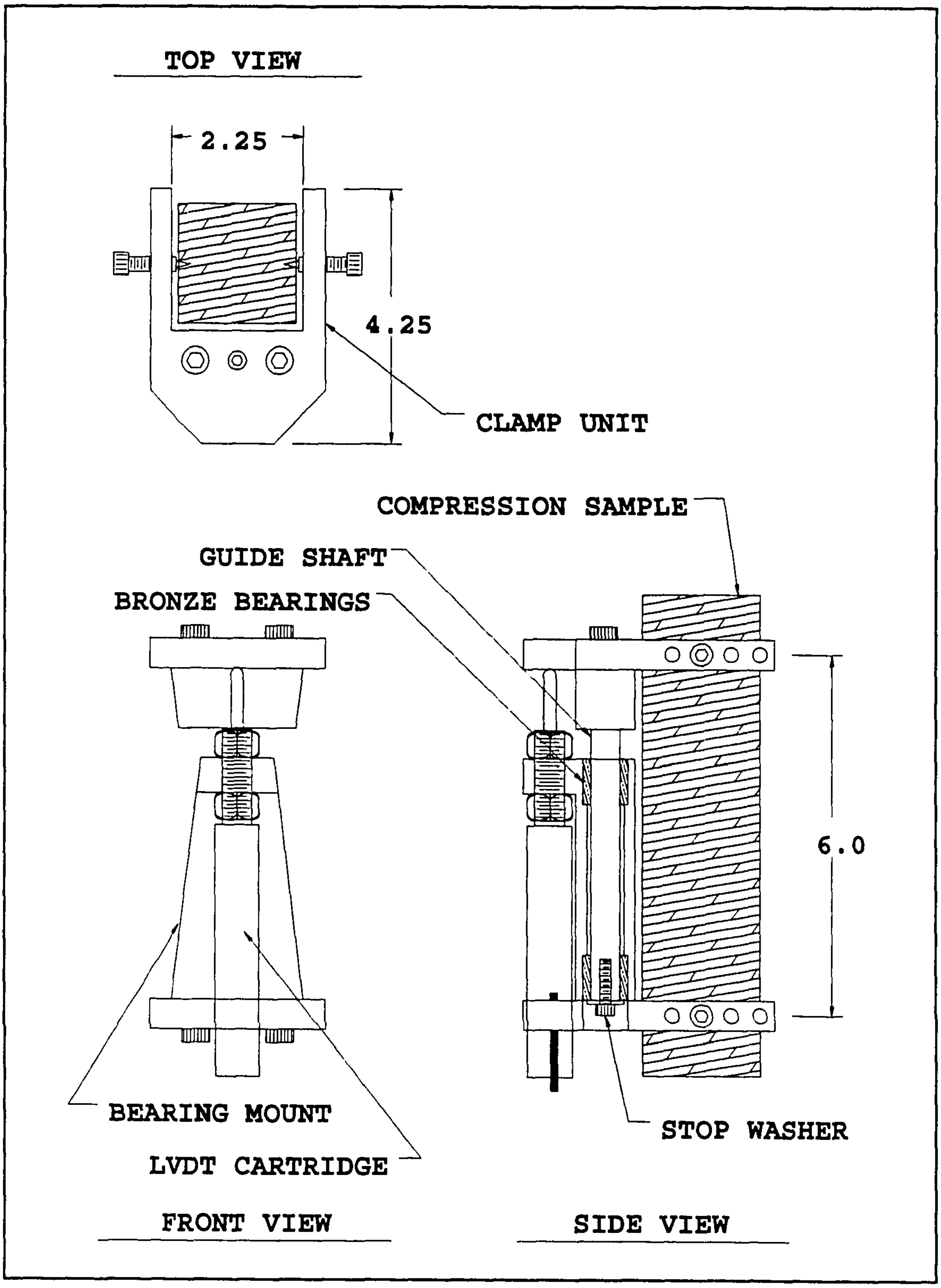

FIGURE 4.5 WOOD COMPRESSOMETER

a spring loaded LVDT cartridge, while the upper clamp bears against the LVDT prod. Thus, as the sample compresses under load, the distance between the two clamp units shortens, and the LVDT prod is displaced, allowing the deflection due to compressive loading to be measured and recorded.

A hardened, polished steel guide shaft is used to connect the two clamps to each other, maintaining alignment between the two clamps. The guide bar is rigidly affixed to the upper clamp, and runs in a two bearing guide arrangement mounted on the lower clamp. The bearings are standard bronze bushings and allow rotation and free linear movement of the shaft with minimal friction. The end of the guide shaft is equipped with a stop washer.

Prior to mounting the compressometer on a sample, the gauge length is set by pulling the two clamp units apart. The stop washer bears on a restraining plate when the gauge length is reached. The gauge length of the compressometer constructed for this study measures 5.987 inches.

The loading platens used for this test are 12 inch hardened steel platens furnished by MTS corporation. The upper platen is equipped with a spherical bearing seat to account for any lack of parallelism present in test samples.

The load cell used for this test has a capacity of 50 kips, with a maximum error of .05% of any given load reading. The LVDT used in the compressometer has a total travel of 0.5 inches, with a linearity of .20% The use of a fifth order polynomial calibration equation allows an LVDT accuracy of slightly better than .00001 inches within the proportional range, and about .0001 inches in the region past the proportional range. This exceeds ASTM requirements. The MTS loading frame is placed in a ±1 inch travel range for this test procedure.

4.4.2.3 Compression Parallel to Grain Test Procedures

Samples for this test are prepared by either cutting sections from previously tested static bending beams, or by table sawing specimen sticks to the required size. Both sample sources are acceptable by ASTM D143. In either case the ends are cut true and smooth on a disk sander. Prior to testing, samples are stored in covered plastic boxes to minimize changes in moisture content. To prevent failure at the end of green samples, the samples are piled and covered, leaving the ends exposed to air dry for about an hour. This hardens the ends sufficiently to allow testing. Seasoned specimens gathered from Birch Lake required no such treatment.

As a sample is removed from the box for testing, the cross sectional dimensions are measured using digital calipers to the nearest .001 inch. Length is measured using a precision grade steel machine ruler to the nearest .01 inch. Sample weight is measured using a digital balance to the nearest .1 gram.

All the measured data is entered into the testing software, and the compressometer attached to the sample after the gauge length is set. The specimen is placed between the loading platens, and centered using concentric rings ground into the face of the platens. A preload of 20±5 pounds is applied to fixture the specimen.

The test is initiated at a constant displacement rate of .024 inches per minute. The data collection equipment samples the time, load, sample deflection, and displacement of the lower platen at a rate of once per second. This continues until the load has peaked. Frequently it is desirable to run the test until well after the peak load to allow the failure pattern to become visible.

The specimen is removed from the load frame, and notes are made which describe the failure. A cube is cut from near the failure for moisture content determination.

A total of 102 samples were tested in the green condition, and 167 samples were tested in the seasoned condition. Data from these tests is provided in Appendix B. Analysis of the data obtained will be discussed in Chapter 5.

4.4.3 Compression Perpendicular to Grain

The compression perpendicular to grain test is performed by applying a load to the side of a timber sample. Load is applied until the load causes a specified amount of deformation in the specimen. This test may be used to determine a modulus of elasticity perpendicular to the grain, and to obtain load limits for side grain bearing in wood.

4.4.3.1 ASTM Requirements

ASTM D143 provides specifications for the compression parallel to grain test along with requirements on the number and type of specimens needed (1). The perpendicular compression test is conducted using 2 by 2 by 6 inch nominally sized specimens. The actual dimensions of the sample are measured prior to testing. Samples may contain defects, provided these defects are not located under the point of load application.

The sample is to be tested between the platens of a load frame. In addition to the platens, a steel loading block 2 inches wide is placed in the middle of the specimen at right angles to the top of the specimen. Thus, given a sample width of 2 inches, 4 square inches of sample area are placed in compression perpendicular to the grain. The samples are oriented such that the load is applied to the radial surfaces.

The load is applied at a constant rate of .012 inches per minute. The test is to be conducted until at least .1 inches of total compression has been attained. Compression is to be measured between the loading platens and read to the nearest .0001 inches.

No notes describing failure are required, as the visual failure effects are not readily apparent. Immediately after the test, a section is cut from the middle of the sample for moisture content determination.

At least one compression perpendicular to grain test is to be performed for every two static bending tests performed. Thus, half of the static bending specimen sticks are to be tested in perpendicular compression. This results in roughly 50 tests for each of the green and seasoned states.

4.4.3.2 Compression Perpendicular to Grain Apparatus

The apparatus used for the compression perpendicular to grain tests consists of two steel plates used in conjunction with MTS compression platens. The steel plates fasten to the platens using magnets.

The first plate is attached to the bottom platen, and measures 2 1/4 inches by 6 1/4 inches. This plate is used to center the specimen on the lower platen.

The second plate is attached to the upper platen at right angles to the lower plate, and measures 2 inches by 6 inches. This plate meets the loading block requirements given by ASTM.

Compression of the specimen is measured using the LVDT built into the loading ram of the MTS load frame. This LVDT is used a ±1 inch range. Calibration data for this LVDT has been fitted with a linear calibration equation allowing accuracy of .0001 inch. As loads encountered in the perpendicular compression test are small enough that any displacements in the load frame are small compared to the specimen deformation, the LVDT in the loading ram effectively measures the compression between the platens.

The load cell used to test the green specimens has a capacity of 5000 pounds, with a maximum error of .018% within the encountered testing limits. The load cell used to test the seasoned samples consisted of a 50 kip cell used in a 10 kip load range with a maximum error of .02%.

4.4.3.3 Compression Perpendicular to Grain Procedures

Samples for the perpendicular compression test are taken from sound sections of previously tested static bending specimens. These sections are bandsawed to length, and the edges sanded to remove burrs which prevent the specimen from sitting flat on the platens. Prior to testing, specimens are stored in a covered plastic box to minimize changes in moisture content.

As a sample is removed from the storage box, the dimensions are measured to .001 inch with digital calipers. Weight is measured to .1 gram using a digital balance.

All of the testing data is entered into the testing software, and the test specimen centered on the lower bearing plate. The lower platen is raised to bring the specimen into contact with the upper loading block, and a preload of 10±5 pounds is applied.

The test is initiated at a constant displacement rate of .012 inches per minute, which is maintained until .1 inch of compression has been achieved, at which point the test is stopped. The data collection system samples time, load, and compression once per second.

At the conclusion of the test, a moisture cube is cut from the middle of the test specimen, and sealed in a metal can to await weighing and moisture content determination.

A total of 73 samples were tested in the green condition, and 65 samples in the seasoned condition. Data from these tests is available in Appendix B. Analysis of the collected data is discussed in Chapter 5.

4.4.4 Hardness Test

The hardness test consists of creating an impression in a test specimen by pressing a steel ball one-half its diameter into the specimen. The hardness is considered to be the load needed to obtain this indentation. The hardness test represents the resistance of the wood to marring, and is not a structural test (17).

4.4.4.1 ASTM Requirements

ASTM D143 provides specifications for the hardness test, along with requirements for sample type and testing frequency (1). The hardness test is conducted using 2 by 2 by 6 inch nominal specimens with the actual dimensions measured at test time. Defects are allowed in the specimens, provided none are near the hardness test sites.

The test is conducted by pressing a steel ball or spherical prod measuring .444 inches in diameter into the specimen to a depth of .222 inches. Depth of penetration is to be indicated by contact between the ball support collar and the specimen.

Six impressions are made on each test specimen with two impressions on radial faces, two impressions on tangential faces, and one impression on each end of the specimen. Penetrations must be far enough away from the edges and defects to prevent splitting or chipping.

The penetrations are created by moving the support platens at a continuous rate of .25 inches per minute until the required depth has been achieved.

Failure patterns consist of a spherical depression in the specimen, and are similar for all test results. Immediately after the test, a section one inch long is to be cut out of the test specimen for moisture content determinations.

At least one hardness test is to be conducted for every two static bending tests. Thus half of the static bending specimen sticks are to be tested in hardness. This results in approximately 50 hardness tests in each green and seasoned wood.

4.4.4.2 Hardness Test Apparatus

The apparatus used for the hardness test consists of a solid loading platen which attaches to the MTS loading ram, and a fabricated ball-ended impression prod which attaches to a load cell. Use of the load cells allows automatic electronic data collection. The hardness test apparatus is shown in Figure 4.6.

No balls of .444 inch diameter were available. As such, a ball of .4375 inch diameter was substituted. The impression depth used was the same as that required in ASTM D143, .222 inch. The difference in impression volume is 4 % which is not believed to be significant for this type of test.

The steel ball is held on the end of a support bar by a magnet in a spherical depression cut into the bar. This support bar provides a large, flat area surrounding the ball, such that .222 inch of the ball projects from the area. Thus, when the ball has penetrated to the correct depth, the collar immediately begins bearing on the test specimen, and the load increases dramatically. This load increase is used to indicate when the indentation of .222 inches has been achieved.

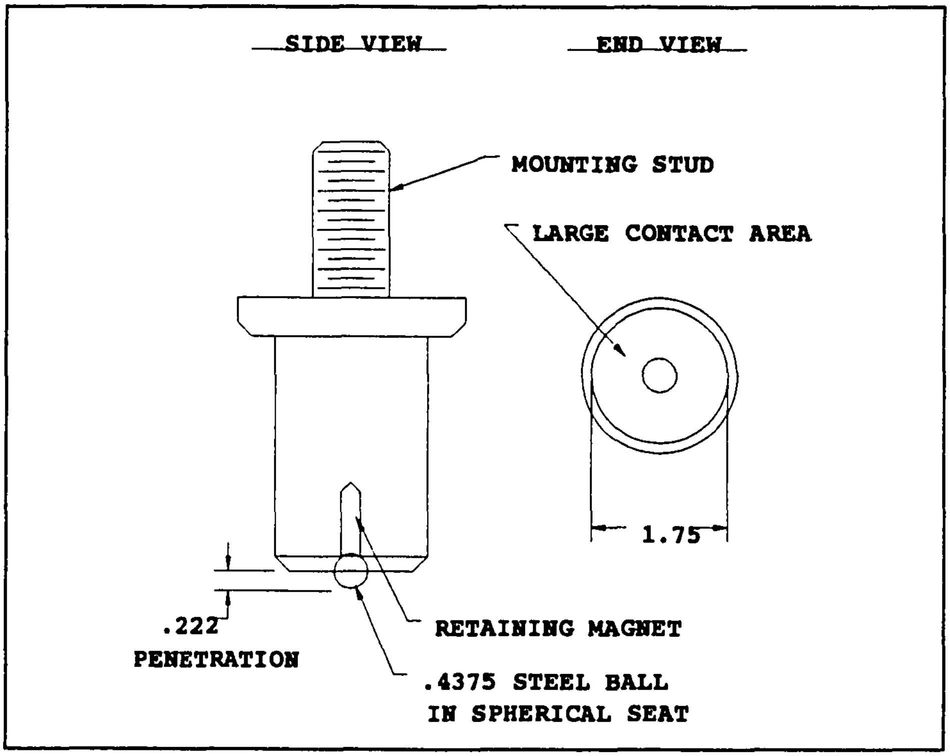

FIGURE 4.6: HARDNESS APPARATUS

The load cell used for this test has a capacity of 5000 pounds, with a maximum error of .018% within typical testing limits. No displacement measurement is required for this test, although the MTS LVDT is used on a ±1 inch range for the purposes of controlling the loading rate.

4.4.4.3 Hardness Test Procedures

Samples for the hardness test are prepared either by table sawing samples from stored specimen sticks, or by trimming sections from previously tested static bending specimens. The ends are sanded to true them and remove burrs which prevent the specimen from lying flat. Prior to testing, samples are stored in a plastic box with close fitting lid to minimize changes in moisture content.

As a sample is removed from the storage box, the dimensions are measured to the nearest .001 inch with digital calipers. Weight is measured using a digital balance to .1 gram.

All of the measured data is entered into the testing software, and the sample placed underneath the ball prod. The test is initiated, and time and load data are collected by the data collection equipment at a rate of once per second. As soon as the prod bears on the sample, as indicated by a rapid load increase, the test is stopped. The sample is then repositioned for the next impression, and the process repeated. Six impressions are made in each specimen, one on each face. The data is stored on the computer's hard disk.

The specimen is removed from the test apparatus, and a moisture cube is cut from the middle of the specimen. The cube is sealed in a metal can until weighing and moisture content determination are performed.

A total of 62 samples were tested in the green condition, and a total of 55 samples were tested in the seasoned condition. Data from these tests is given Appendix B. Analysis of the collected data will be discussed in Chapter 5.

4.4.5 Shear Parallel to Grain

The shear parallel to grain test is accomplished by applying a load to a test specimen in such a manner that the specimen fails by separation and slippage of the wood fibers relative to each other in a direction parallel to the grain. The shear test may be used to determine the allowable stress for a species.

4.4.5.1 ASTM Requirements

ASTM D143 provides specifications for the shear parallel to grain test, along with requirements on the number and type of specimens needed (1). ASTM favors a type of shear test referred to as the single shear test. This test is performed using a notched cube with overall dimensions of 2 by 2 by 2 1/2 inches of the geometry shown in Figure 4.7. The shearing area of such a sample is approximately 4 square inches. The actual dimensions of the shearing surface are measured prior to testing.

The test specimen is mounted in a sturdy clamp arrangement, such that the 2 1/2" portion of the specimen is fastened into the fixture. Load is applied through an adjustable seat, with an offset of 1/8 inch between the inner edge of the supporting surface and the plane along which failure occurs. Care must be taken to ensure that the specimen is vertical and that the ends rest evenly on the support over the contact area.

Load is to be applied by constant displacement of the loading seat at a rate of .024 inches per minute. The test is stopped at failure. Failure is indicated by the load decreasing after a peak is obtained. Only the maximum load need be recorded.

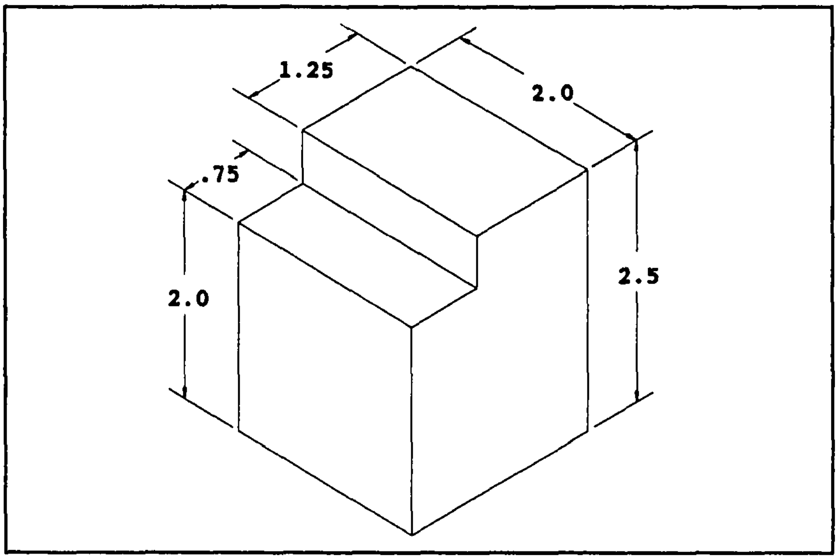

FIGURE 4.7: SINGLE SHEAR TEST SPECIMEN

After the test, notes describing the failure are taken, and a sketch is made of the sample. Should the failure surface extend back into the supporting surfaces (i.e. the 2 1/2 inch section), the test results are to be discarded. One of the two halves of the failed specimen shall be used as a moisture cube.

Twelve shear parallel to grain specimens are to be taken from six of the sticks tested in static bending per bolt. The shear parallel to grain samples are obtained in pairs, with one sample to be sheared with the growth rings located in a tangential manner, and one with the rings located in a radial manner. With an average sample site yielding 16 bolts, 96 sticks should be used for shear specimens. Half of these specimens are tested green, and half tested seasoned. Thus, 48 pairs of samples are tested green, and 48 pairs tested seasoned. The samples are to be selected in the following proportions: 1 sample near pith and 1 sample from the log periphery per every 4 samples of the average log section.

4.4.5.2 Shear Parallel to Grain Test Apparatus

Two procedures for shear testing were used due to difficulties with the ASTM prescribed single shear test. The ASTM single shear test was used for the green wood samples, but did not give reasonable results for the seasoned specimens, for reasons to be explained. As such, an alternate test, referred to as the double shear test (sometimes called the shear cross test) was used for the seasoned wood.

The apparatus used for the single shear test is shown in Figure 4.8. This apparatus uses a clamp bar to restrain the shear specimen of Figure 4.7. This bar is prevented from rocking or translating by the upright supports enclosing the clamp bar. The shearing load is applied through a hook shaped bracket which reaches underneath the notched specimen. A 1/8 inch separation is provided between the edge of the clamp bar, and the loading bracket. The loading bracket is fastened to a load cell via a ball joint arrangement and a clevis yoke; this arrangement allows the loading seat to continuously self-adjust throughout the test. A stop located behind the loading bracket enables consistent placement of the specimen beneath the clamp bar and against the loading bracket.

This apparatus was partially successful, particularly at shearing the green specimens which fail at low loads. However, due to the eccentric loading of the specimen required by the design of the single shear test apparatus, large twisting forces are generated in the specimen. This rotates the specimen such that tensile forces are applied across the grain of the specimen. This causes a cleavage failure across the grain, rather than a shear along the grain. These failures occur at much lower loads than typical shear tests as reported in the literature (15,16,17). This behavior was more of a problem with the seasoned specimens, which fail at higher load levels.

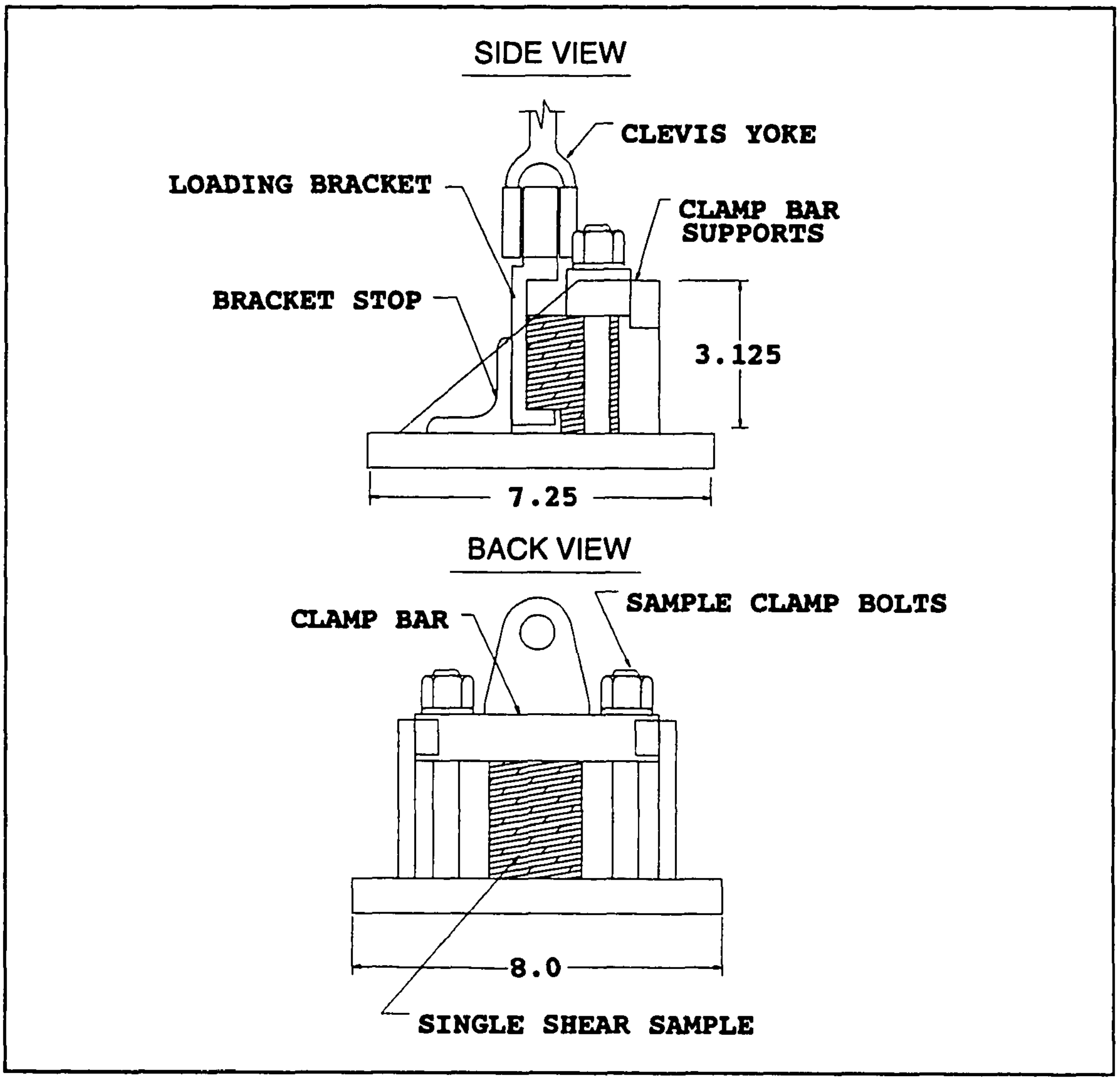

FIGURE 4.8: SINGLE SHEAR APPARATUS

While the single shear test is an ASTM standard, it is not apparent how the test is to be performed so as to avoid the cleavage failures. As considerable difficulty was encountered while using the above described apparatus, it was decided to use the double shear test as described by Kollman and Cote (20) for the seasoned samples.

The double shear test is performed using a specimen of the cruciform shape shown in Figure 4.9, which is referred to as a shear cross. This specimen is supported along the two bottom notches, while the shearing load is applied by compression of the projecting upper segment. This results in shear failure through two planes, and hence is called a double shear test. This test eliminates the eccentric loading problems of the single shear test. Results from the double shear tests reported in the literature correspond very closely to those from single shear tests (20).

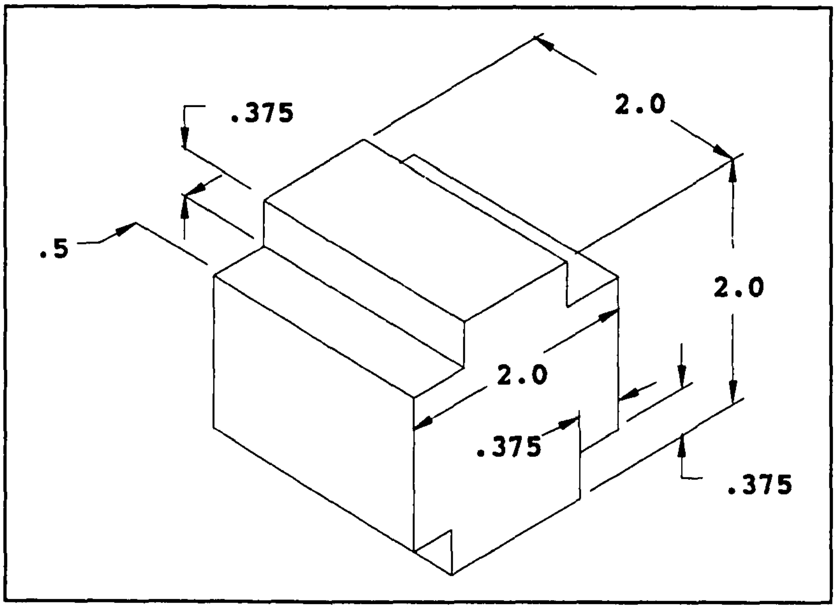

FIGURE 4.9: DOUBLE SHEAR SPECIMEN

Apparatus for the double shear test consists of a small machine vise with parallel, flat-top jaws which are used to lightly grip the base of the specimen. The vise holding the specimen is placed between the compression platens of the loading frame. Compressive loads are then applied to the top of the specimen at a rate of .024 inches per minute.

The load cell used for the single shear test has a capacity of 5000 pounds, with a maximum error of .018% over the typical testing range. As the double shear test requires a higher load, a 50 kip load cell is used, with the load cell amplifier range selected to create an effective load limit of 10 kips. Used in this fashion, the load cell has a maximum error of about .02%. Displacement measurements are not required for this test. The MTS loading frame is placed in a ±1 inch travel range for this test series.

4.4.5.3 Shear Parallel to Grain Test Procedures

Samples for shear testing are taken from sections remaining from sticks tested in static bending. Samples are prepared by bandsawing pairs of cubes from the selected static bending sticks. Test specimens for the single shear test are notched using a bandsaw jig, while the specimens for the double shear test are notched using a vertical milling machine. From each pair of cubes cut from a single specimen stick, one radial shear-plane sample and one tangential shear-plane sample are fabricated. Prior to testing, specimens are stored in a covered plastic box to avoid moisture content changes.

As a sample is removed from storage for testing, the dimensions of the shear plane are measured using digital calipers to the nearest .001 inch. Sample weights are measured using a digital balance, read to the nearest .1 gram.

All of the measured data is entered into the testing software, with a file name which indicates whether a radial or a tangential sample is being tested. This is done by replacing the sample's site number with either R or T, accordingly.

Samples are then placed into the test apparatus. In the case of the single shear test, the specimen is placed under the clamping bar and over the loading bracket. It is secured by firmly tightening the clamping bar nuts with a wrench. For a double shear test, the base of the sample is lightly clamped in a machine vise, and then centered between the loading platens of the MTS frame.

The load is then applied and time, load, and ram position data are automatically collected at the rate of once per second. After failure has occurred as defined by a sudden decrease in load carrying capacity, the test is stopped, and data stored to computer hard disk. The specimen is removed from the apparatus, failure notes made, and the specimen is placed in a metal can to await moisture content determination.

A total of 19 pairs of samples were tested as single shear specimens in the green condition, and a total of 56 pairs were tested as double shear specimens in the seasoned condition. Data from these test results is available in Appendix B. Analysis of the collected data is dealt with in Chapter 5.

4.4.6 Cleavage Test

The cleavage test is a test of tensile strength perpendicular to grain (20). In the cleavage test, a notch at one end of a specimen is loaded in such a way that tensile stresses perpendicular to the grain develop. These stresses result in a split that rapidly propagates through the sample starting at the notch.

4.4.6.1 ASTM Requirements

ASTM D143 (1) provides specifications for the cleavage test, along with requirements for sample geometry and testing frequency. The cleavage test is conducted using a nominal 2 by 2 by 3 3/4 inch sample with a circular notch at one end as depicted in Figure 4.10. The actual dimensions of the failure surface are to be measured prior to testing. Defects in the sample are allowable at the end of the specimen opposite the notch.

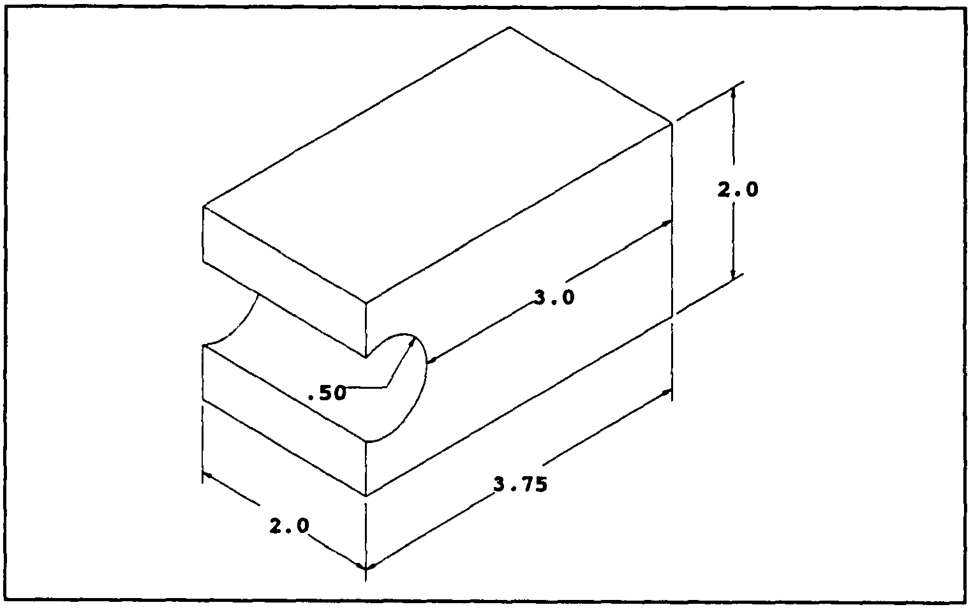

FIGURE 4.10: CLEAVAGE SPECIMEN

The test is conducted using two L shaped arms which pull on opposite sides of the specimen notch as shown in Figure 4.11. The loading arms feature rounded pads at the points they contact the test specimen. The loading arms mount on the testing frame with clevis yokes. This allows the arms to continuously self adjust during the test procedure.

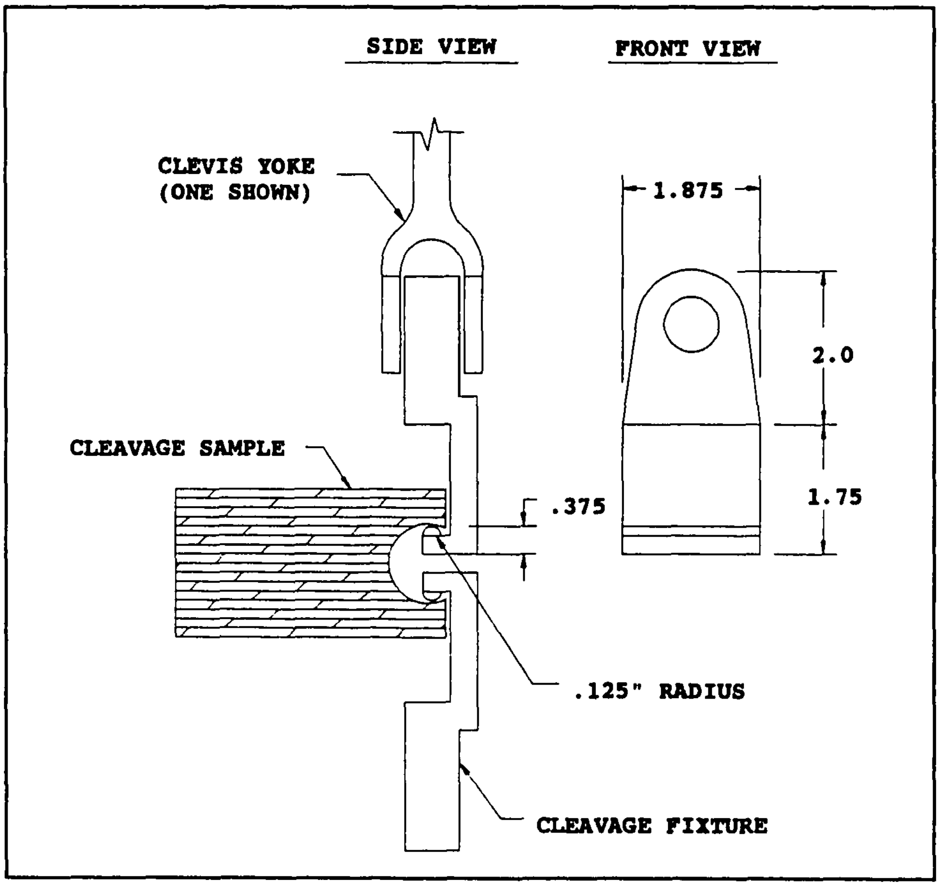

FIGURE 4.11: CLEAVAGE APPARATUS

Load is applied by moving the loading arms apart at a constant displacement rate of .10 inches per minute, until the specimen has failed, separating into two separate pieces. Only the maximum load need be observed.

Notes regarding the failure pattern are made after the test. One half of the broken test specimen is used for moisture content determinations.

Six pairs of tests are conducted per bolt. A pair of test specimens consists of a radial specimen and a tangential specimen cut from the same piece of wood. At least 48 pairs of samples are to be tested green, and 48 pairs tested seasoned. The samples are to be selected in the following proportions: 1 sample near pith, and 1 sample from the log periphery per every 4 samples of the average log section.

4.4.6.2 Cleavage Test Apparatus

The apparatus for the cleavage test consists of two L shaped arms as described in Section 4.4.6.1, and as illustrated in Figure 4.11. The apparatus matches the pattern specified by ASTM, with the addition of spherical ball joint assemblies which are used to attach the clevis yokes to the loading frame. The use of ball joints in conjunction with the clevis yokes allows for more adjustment latitude.

The load cell used for this test has a capacity of 5000 pounds, with a maximum error of .018% within typical testing limits. No displacement transducer is required for this test. The MTS loading frame is used on a ±1 inch travel range for this test procedure.

4.4.6.3 Cleavage Test Procedure

Samples for the cleavage test are either cut from portions of specimens tested in static bending, or are table sawed from stored specimen sticks. The samples are first cut oversized to a length of 4 1/4 inches using a bandsaw. The circular notch in the end of the sample is then cut in the sample with a 1 inch diameter forestner type drill bit using a jig and a drill press. This particular type of drill bit uses four blades, two of which slice the wood fibers around the edge of the hole, while the other two blades lift out the chips. After drilling the notch hole, 1/2 inch is cut off the notched end using the bandsaw, leaving the ASTM sample shown in Figure 4.10. Prior to testing, the samples are stored in a plastic box with fitted lid to minimize changes in moisture content.

As the samples are tested, they are removed from the storage box, and the width and length of the expected failure plane measured to the nearest .001 inch using digital calipers. Weight is measured to the nearest .1 gram with a digital balance.

All of the measured data is entered into the testing software, and the sample placed over the loading arms. A preload of approximately 5 pounds is applied, and the sample's position adjusted on the loading arms. At this point the test is initiated, with the loading arms moving apart at the constant rate of .10 inches per minute. Time, load, and loading ram position data is sampled at a rate of once per second until the sample fails.

The broken sample is removed from the test apparatus, and notes made concerning the failure. The broken test specimen is placed in a metal can to await weighing and moisture content determination.

A total of 30 pairs of cleavage samples were tested in the green condition, and 57 pairs were tested in the seasoned condition. Data from these test results is presented in Appendix B. Analysis of the collected data will be dealt with in Chapter 5.

4.4.7 Tension Parallel to Grain Test

The tension parallel to grain test is performed by applying a tensile load to a long, slender specimen cut such that the grain is running parallel to the direction of load application. This test is used to determine a tensile strength and modulus of elasticity for a timber species.

4.4.7.1 ASTM Requirements

ASTM D143 provides specifications for the tension parallel to grain test, along with requirements on the number and type of specimens needed (1). The parallel tension test is conducted using a specimen cut from a slender 1 by 1 by 18 inch stick, sawn from the larger stored specimen sticks. The test specimen shape is shown in Figure 4.12 and consists of a 2 1/2 inch long gauge section with curved transitions connecting the gauge section to rectangular end sections which are used to secure the specimen in the test apparatus. The gauge area measures 3/16 by 3/8 inch for a nominal area of .07 square inches. The specimen is to be cut such that the tangential plane is perpendicular to the greater cross sectional dimension. The cross section is to be measured prior to testing. No defects are allowable in the gauge area or in the curved transition sections. The elongated, slender shape, in conjunction with the curved transitions ensure the gauge section experiences as close to pure tension as possible, and minimizes end effects in the failure zone.

The test specimen is mounted using fixtures which slip over the ends of the specimen. The specimens bear against the test fixtures through the notches cut into the sides of the specimens, rather than being clamped. This prevents slippage of the specimen during the test (see Figure 4.13). Load is applied by constant displacement of the mounting fixtures at a rate of .05 inches per minute.

The test is conducted until the sample fails as indicated by a sudden separation. Sample extension is to be measured over a 2 inch gauge length in the straight section of the sample. Extension is to be measured to the nearest .0001 inch, until the proportional limit is attained.

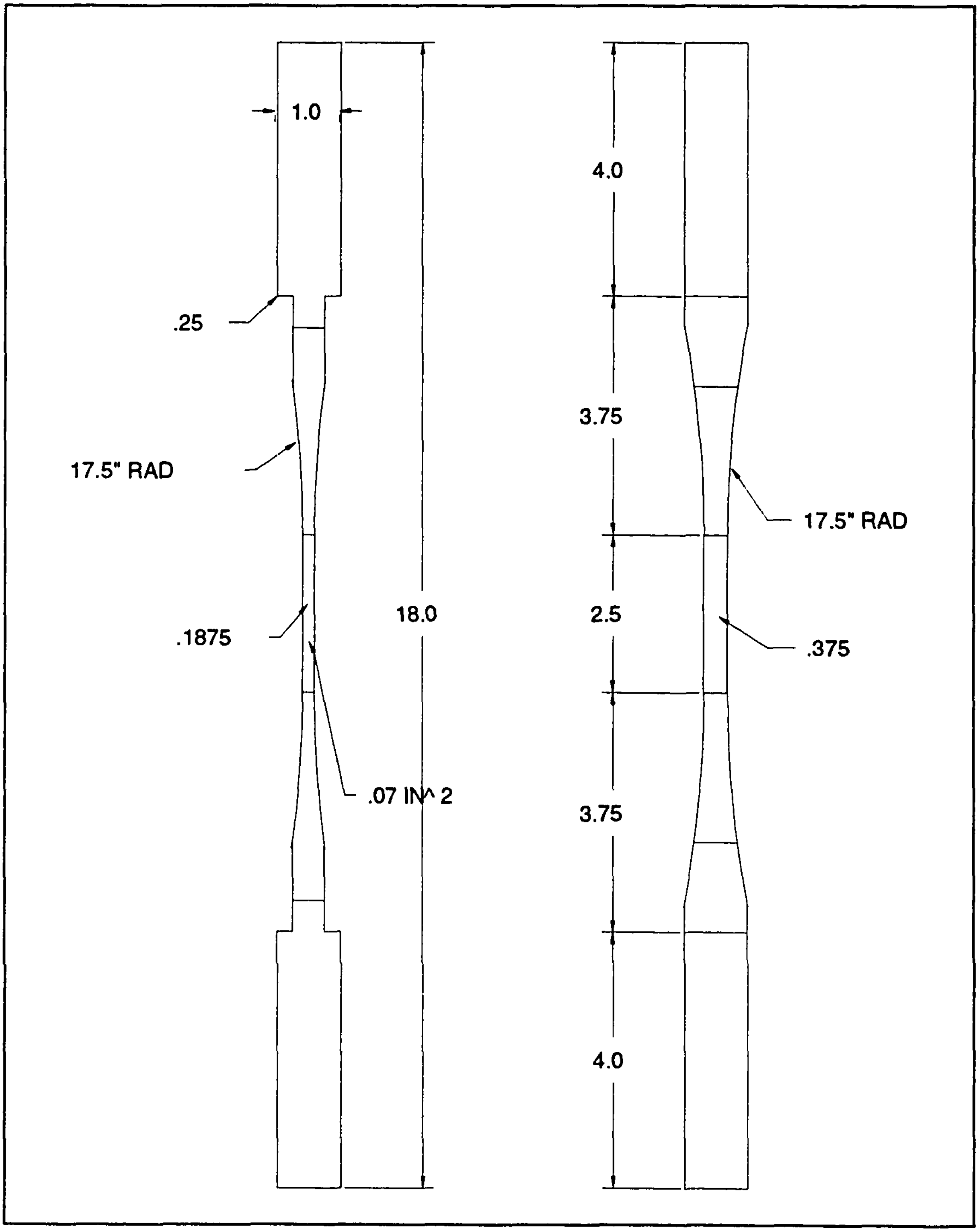

FIGURE 4.12: PARALLEL TENSION SPECIMEN

Failure notes are made which describe the appearance of the failure surfaces. Test results for samples that fail outside of the gage area are to be discarded. A 3 inch portion near the failure is to be used for moisture content determination.

Six tension parallel to grain tests are made for each of the typical bolts, with half of these tests being performed on green wood, and half on seasoned wood. Given a typical sample site yield of 16 large diameter bolts, a total of 48 samples are to be tested green, and 48 tested seasoned. The samples are to be selected in the following proportions: 1 sample near the pith, and 1 sample from the log periphery per every 4 samples of the average log section.

4.4.7.2 Tension Parallel to Grain Test Equipment

The equipment used for the tension parallel to grain test consists of two steel blocks fabricated as illustrated in Figure 4.13 The cut-outs are slightly larger than the size specified by ASTM to allow for variation in the size of the gripping portion of the specimen sticks. The two tension fixtures are attached to the loading frame using spherical ball joints to allow for self-alignment of the test specimens.

To prevent specimen rotation within the fixtures due to unevenness in the shoulders of the test specimens, tapered shims are used to wedge the specimen into the grips, as indicated in Figure 4.13. These shims serve to prevent bending moments in the tension specimen, and are not capable of transferring any tensile loading. All of the tensile loading reaches the specimen through the shoulders.

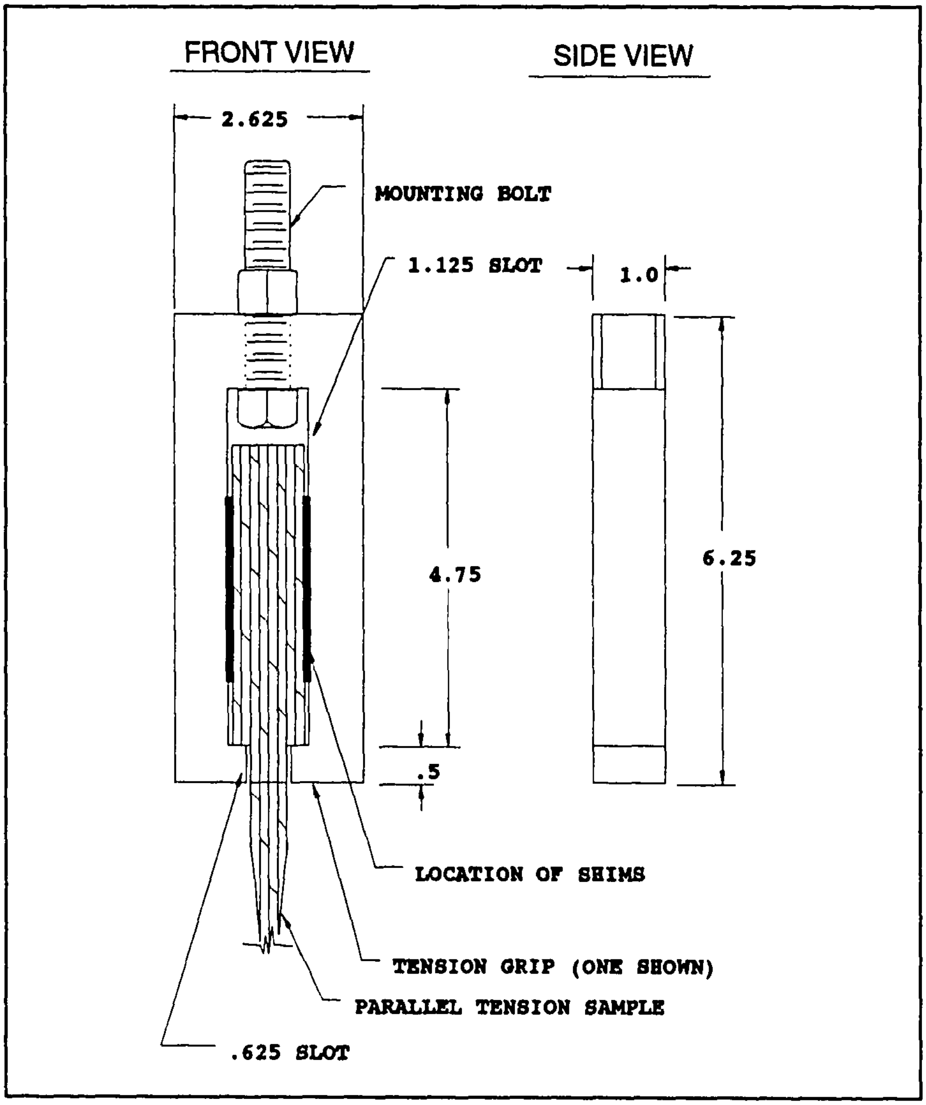

FIGURE 4.13: PARALLEL TENSION GRIPS

The load cell used for this test procedure has a capacity of 5000 pounds, with the output amplified to provide an effective capacity of 2500 pounds. Used in this fashion, the load cell has a maximum error of .028% over the typical testing range. Extension is measured using a 2 inch gauge length clip-on type strain gauge extensometer manufactured by MTS. This gauge has a maximum extension range of 1 inch, and may be left on the tension specimen past failure. The gauge was used in a ±.1 measurement range. When used in this range, the gauge may be calibrated using a linear equation to a minimum accuracy of .00001 inches. The MTS loading frame is used in a ±1 inch travel range for this test procedure.

4.4.7.3 Tension Parallel to Grain Test Procedures

Samples for the tension parallel to grain test are prepared by table sawing 1 by 1 by 18 inch sticks from stored specimen sticks and then cutting the sample geometry on a bandsaw. To achieve consistent sample dimensions, a specialized jig was constructed to hold and cut the complex sample geometry into the sample blank.

The jig consists of a base plate which mounts on a bandsaw, a slider assembly with pivot which slides on the baseplate, and a specimen holder which rotates on the slider's pivot. Several travel stops and adjustments control the motion of the various pieces of the jig. The operator fastens an uncut test specimen in the jig, and then pushes the specimen through the saw blade. The jig controls the shape of the cut. Repeating this process for the other three sides of the blank produces a tension specimen which still needs the loading notches cut in the ends. The notches are also cut with the bandsaw. Specimens are given a light sanding on a belt sander to remove saw marks and burrs. Samples are stored in a covered plastic box prior to testing to minimize moisture content changes.

In preparation for testing, a specimen is removed from the storage box, and the gauge area is measured using digital calipers to the nearest .001 inch. Sample weight is measured using a digital balance to the nearest .1 gram.

All of the measured data is entered into the testing software. The extensometer is attached to the gauge area using rubberbands, and the sample loaded as follows.

The specimen is placed in the lower grip, and thin aluminum wedges are used to fill gaps between the sample and the grips. A load of up to 20 pounds is then applied to align the sample in the lower grip. The load is removed, allowing the upper grip to float around the specimen. Aluminum wedges are then placed in the upper grip to fixture that end of the specimen. Finally, a preload of 10±5 pounds is applied to align the sample in the upper grip. This procedure ensures the sample is not twisted in the grips, which would cause a low failure load by inducing shear effects.

The test is initiated at a constant displacement rate of .05 inches per minute. The data collection equipment records time, load, extension, and loading ram displacement at the rate of once per second.

At the conclusion of the test, the extensometer is removed, and notes regarding failure made. One-half of the failed specimen is used for moisture content determination.

A total of 47 seasoned samples were tested in parallel tension. No parallel tension tests were performed on green wood. Data for these tests is available in Appendix B. Analysis of the collected data may be found in Chapter 5.

4.4.8. Tension Perpendicular to Grain Test

The tension perpendicular to grain test is similar in intent to the cleavage test of Section 4.4.6. In this test, however, the sample being tested is placed under uniform tension, rather than the non-uniform tension gradient with stress concentration used in the cleavage test.

4.4.8.1 ASTM Requirements

ASTM D143 provides specifications for the tension perpendicular to grain test, along with requirements for sample geometry and testing frequency (1). This is an optional test not required by ASTM, as results from the cleavage tests may be used to develop perpendicular tensile strength values (20).

The tension perpendicular to grain specimen consists of a 2 by 2 by 2 1/2 inch cube with two circular notches cut across the end grain of opposite ends. This test specimen is shown in Figure 4.14. No defects are allowed between the two notches.

The perpendicular tension test apparatus are depicted in Figure 4.15. This consists of two assemblies with arms which fit into the circular notches at either end of the test specimens. These loading arms have curvatures matching the curvature of the notches. One assembly is placed on each side of the specimen, trapping the specimen in the middle.

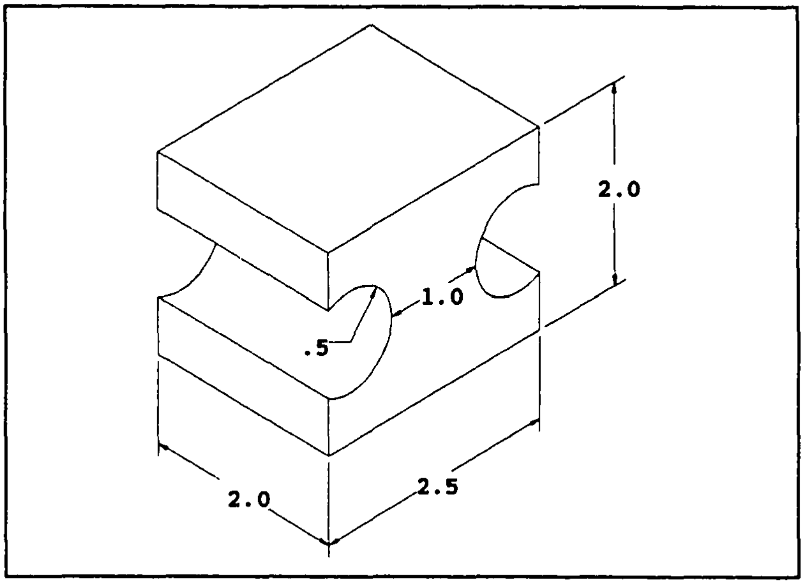

FIGURE 4.14: PERPENDICULAR TENSION SAMPLE

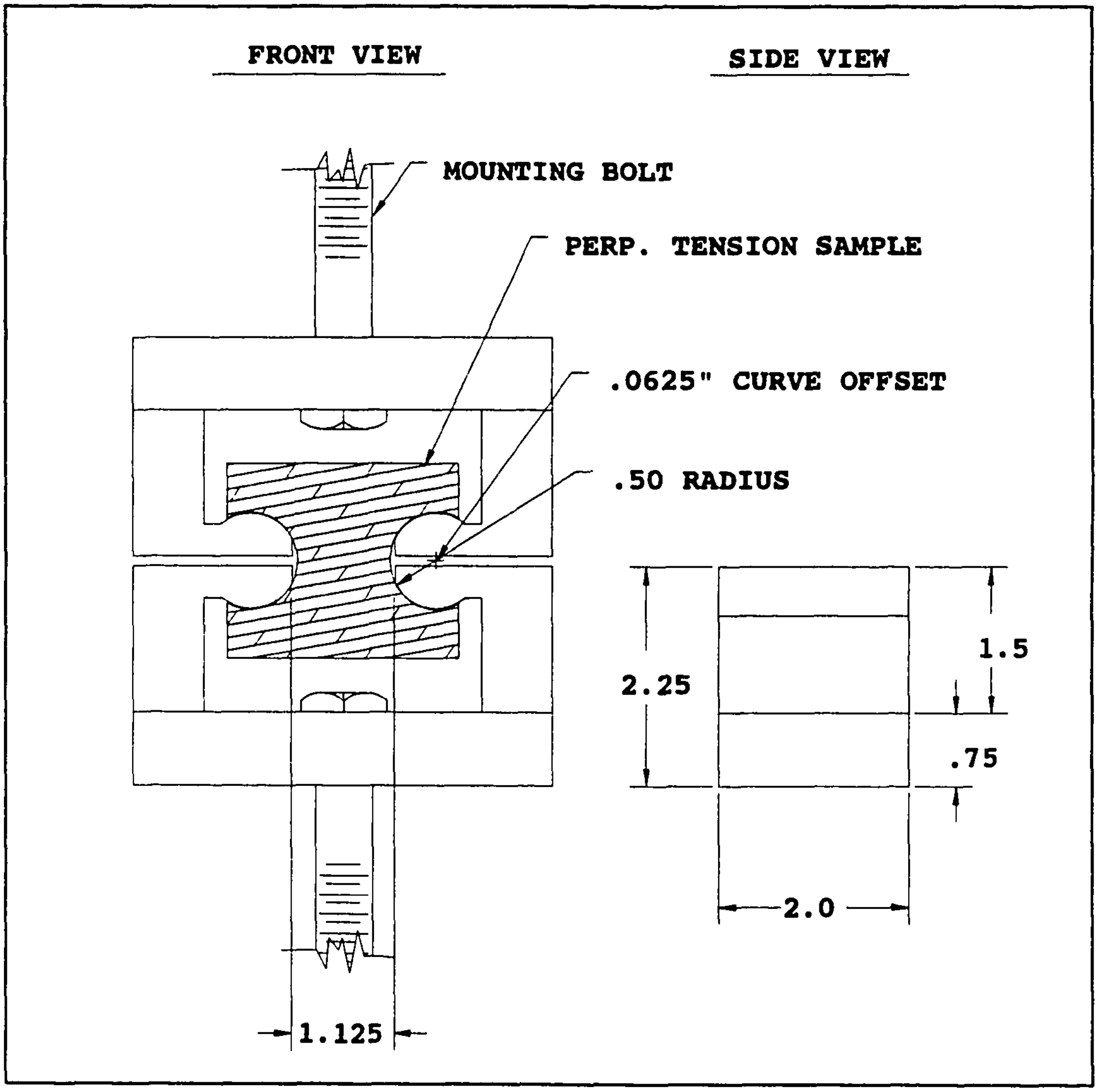

FIGURE 4.15: PERPENDICULAR TENSION GRIPS

Load is applied to the specimen by constant displacement of the test grips at a rate of .10 inches per minute until failure occurs. Failure is defined as the separation of the two specimen halves. Only the maximum load attained need be recorded. Notes regarding the failure are to be made, and one of the broken specimen halves retained for moisture content determination.

The number of specimens to test in perpendicular tension is determined in a manner similar to the procedure for shear testing described in Section 4.4.5.1 with six pairs of tests being conducted per bolt. A pair of test specimens consists of a radial specimen and a tangential specimen cut from the sample piece of wood. From a typical sample site of five 24 inch trees, about 48 pairs of samples are to be tested green and 48 pairs tested seasoned. The samples are to be selected in the following proportions: 1 sample near pith, and 1 sample from the tree periphery per every 4 samples of the average section.

4.4.8.2 Tension Perpendicular to Grain Equipment

The apparatus for the perpendicular tension test consists of two L shaped arms bolted to a mounting block. The L shaped arms are formed by welding round sections onto flat bar, followed by milling and grinding to the pattern shown in Figure 4.15. This produces a testing fixture meeting ASTM requirements, as described in Section 4.4.8.1. Two such assemblies are required.

The loading fixtures are attached to the MTS loading frame using spherical ball joint assemblies in the load cell and loading ram. This allows the fixtures to self-adjust as load is applied to the test specimens.

The load cell used for this test has a capacity of 5000 pounds, with a maximum error of .018% within typical testing limits. No displacement transducer is required for this test, as only the maximum load is desired. The MTS loading frame was used in a ±1 inch travel range for this test procedure.

4.4.8.3 Tension Perpendicular to Grain Test Procedures

Samples for the perpendicular tension test are either cut from pieces of wood left from the static beam tests, or are table sawed from stored specimen sticks. The samples are cut oversized, with a length of 3 1/2 inches. The notches in opposite ends of the sample are cut with a 1 inch diameter forestner type drill bit using a jig and a drill press. After drilling the notch hole, 1/2 inch is cut off each of the notched ends using a bandsaw. This leaves a sample meeting the geometry required in ASTM D143, as shown in Figure 4.14. Prior to testing, the samples are stored in a plastic box with fitted lid to avoid changes in moisture content.

As the samples are tested, they are removed from the storage box, and the minimum length and width of the potential failure plane is measured to the nearest .001 inch using a digital caliper. Measurement of weight is not required for this test.

The measured data is input into the testing software, and the sample placed into the loading fixtures. A preload of approximately 5 pounds is applied to aid in alignment of the fixtures. At this point, the test is initiated, with the loading fixtures moving apart at a constant rate of .1 inches per minute. Time, load, and loading ram position data is sampled at a rate of once per second until the sample fails.

The broken sample is removed from the test apparatus, and notes made concerning the failure. The broken test specimen is placed in a metal can to await weighing and moisture content determination.

A total of 13 pairs of perpendicular tension samples were tested in the green condition, and 55 pairs were tested in the seasoned condition. Data from these test results is presented in Appendix B. Analysis of the collected data will be dealt with in Chapter 5.

4.4.9 Nail Withdrawal Test

The nail withdrawal test consists of applying load to metal nails imbedded in wood samples. The maximum load the nail withstands before pulling out is considered the withdrawal load.

4.4.9.1 ASTM Requirements

ASTM D143 provides specifications for the nail withdrawal test, along with requirements on the number and type of specimens needed. Note that this is an optional test not required by ASTM (1). This is in part because test results are most correct for the specific diameter and type of nail tested; extrapolation to other types or sizes of fasteners may be inappropriate. Allowable nail loadings reported in design documents such as the NDS are commonly developed using empirical formulas based upon the specific gravity of the wood being fastened (17).

The nail withdrawal specimen consists of a 2 by 2 by 6 inch cube, with the actual dimensions and weight being measured at the time of the test. Six nails are to be driven into the cube, two on radial faces, two on tangential faces, and one on each end. Test data for the various directions is to be recorded separately, particularly in the case of end withdrawal. The nails specified in ASTM D143 are nominal .0985 inches in diameter, and of the bright, diamond-point configuration. Nails should have no rust, coatings or films of any sort. These requirements are met by 5d common nails, or 7d cement coated nails, with the cement removed with solvent. Nails are to be used only once.

Nails are to be driven at right angles to the face of the specimen, with a total penetration of 1 1/4 inches. The test nails must be driven sufficiently far away from the sample edges to avoid splitting, and to avoid other nails. A typical nail withdrawal specimen is shown in Figure 4.16.

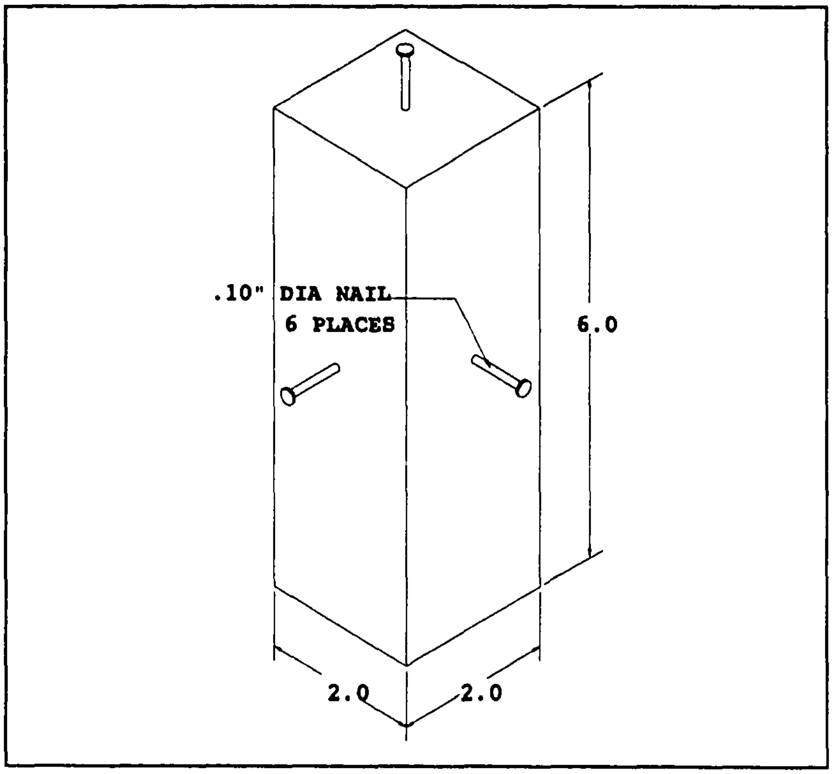

FIGURE 4.16: NAIL WITHDRAWAL SPECIMEN

The nails are withdrawn from the specimen immediately after driving. The nail is withdrawn using a tong like fixture (see Figure 4.17) while the specimen is restrained. Nails are withdrawn at the constant rate of .075 inches per minute. Only the maximum withdrawal load for each nail need be recorded. Moisture contents must be determined on each specimen, as approximate specific gravities are to be calculated from the measured sample dimensions.

Twelve nail withdrawal tests are to be made for each of the typical bolts, with half of these tests being performed using green wood, and half using seasoned wood. Given a typical sample site yield of 16 large diameter bolts, a total of 96 samples would be tested green, and 96 tested seasoned. ASTM requires the specimens to be selected in the following proportions: 1 sample near pith, and 1 sample from the log periphery per every 4 samples of the average log section.

4.4.9.2 Nail Withdrawal Test Apparatus

The apparatus used for the nail withdrawal test procedures is shown in Figure 4.17. The apparatus consists of a restraining fixture, and a withdrawal tong.

The restraining fixture consists of a steel plate mounted to the MTS loading ram in such a fashion as to provide clearance underneath the plate for the nail withdrawal sample. A hole drilled in the steel plate allows the nailhead to pass through the plate, allowing the withdrawal tong to grasp it.

The withdrawal tong consist of a machined steel cylinder, equipped with a slot wide enough to pass the nail's shank, but narrow enough to prevent the head from pulling through. The withdrawal tong is heat treated for durability. This tong attaches to a load cell via a spherical ball joint arrangement which allows the tong to be swiveled for sample loading and adjustment. Withdrawal load is applied to the nail by constant displacement of the restraining fixture while the withdrawal tong stays stationary.

The load cell used for the nail withdrawal test consists of a 5000 pound capacity cell, with the output amplified to create an effective load limit of 500 pounds. Used in this fashion, the load cell has a maximum error of .014% over the typical testing limits. Displacement measurements are not required for this test. The MTS loading frame is placed in a ±1 inch travel range for this test series.

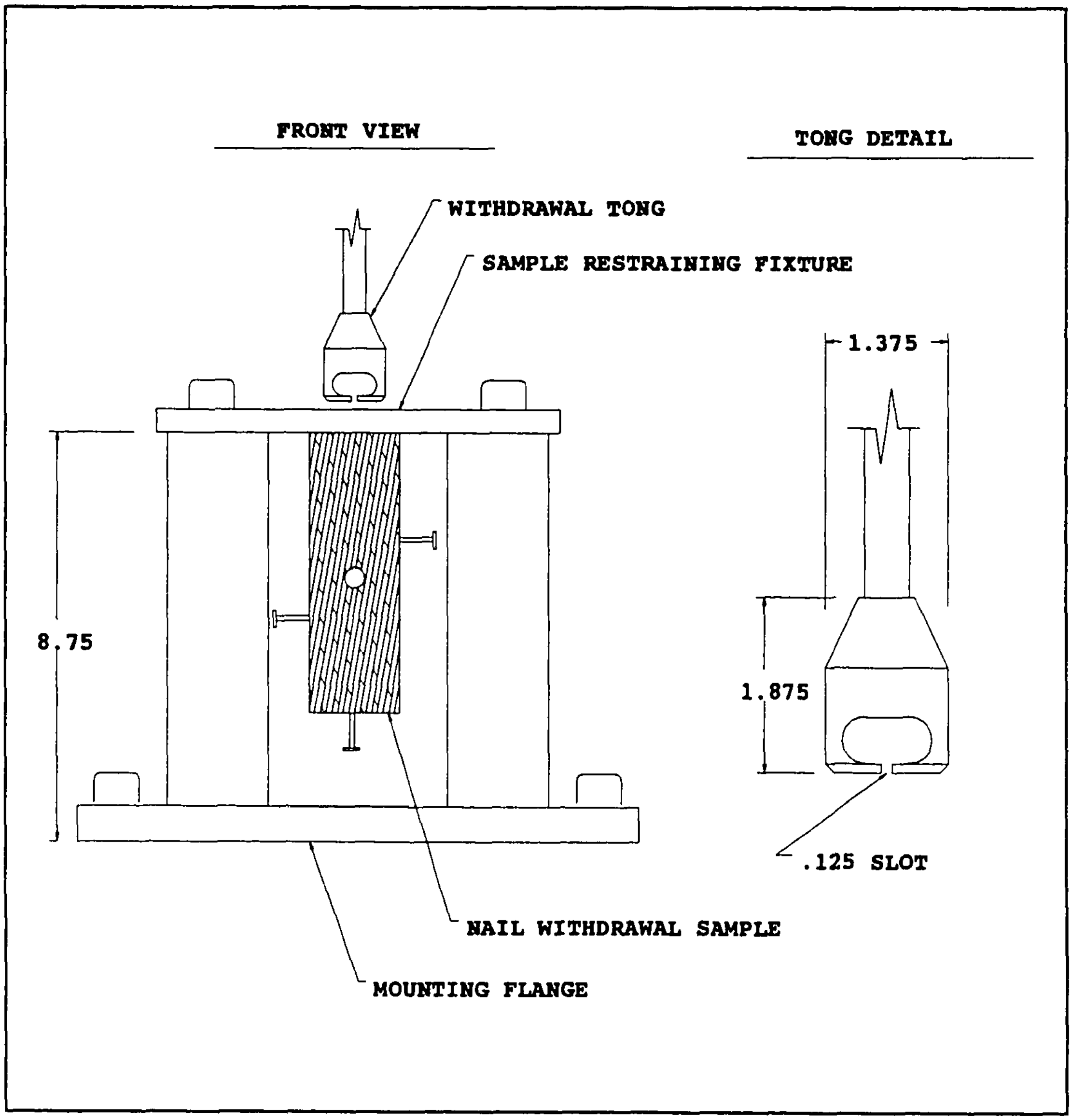

FIGURE 4.17: NAIL WITHDRAWAL APPARATUS

4.4.9.3 Nail Withdrawal Test Procedures

Samples for nail withdrawal testing are taken from undamaged sections of the sticks tested in static bending, or are table sawed from stored specimen sticks. Samples are cut to length with a bandsaw, and ends are cut true and flat using a disk sander. Prior to testing, specimens are stored in a plastic box with fitted lid to minimize moisture content changes.

At testing time, a specimen is removed from the storage box, and the dimensions measured to the nearest .001 inch with digital calipers. Weight is measured to the nearest .1 gram using a digital balance.

All of the measured data is entered into the testing software, and the equipment prepared for the test. At this point, the test nails are driven into the specimen. Driving is accomplished using a nail holder to ensure the nail is set perpendicular to the surface and to the correct depth. The nail holder consists of modified pliers equipped with hardened steel blocks drilled through to provide a clearance hole for the nail. The nail holder is held flat on the specimen surface, and a nail inserted into the clearance hole. The nail is then hammered down flush against the hardened blocks using a 16 ounce hammer. The blocks are 3/4 inch tall, thus allowing 1 1/4 inches of penetration when using 2 inch nails.

Nails used in this test are 6d bright box nails, having a nominal diameter of .101 inch. Common 5d nails, as recommended by ASTM are not currently a standard size, and were not available for testing purposes. Nails are cleaned prior to use with trichloroethane solvent, and stored in sealed metal cans to avoid contamination.

After driving all six nails, the specimen is positioned in the test fixtures, and the first nail withdrawn. Time and load information is collected at the rate of five samples per second. As soon as the maximum load is reached, as indicated by a peak load followed by decreasing load, the test is stopped. The sample is then repositioned for the next withdrawal, and the process repeated for a total of six withdrawals. After the final withdrawal, the data is stored to computer hard disk.

After the final nail withdrawal, the specimen is removed from the fixtures, and the nails discarded. A moisture cube is cut from the middle of the sample, and sealed in a metal can to await weighing and moisture content determination.

A total of 16 samples or 96 withdrawals were conducted on green wood samples, and a total of 55 samples or 330 withdrawals were conducted on seasoned wood. Data from these tests is available in Appendix B. Analysis of the collected data will be dealt with in Chapter 5.

4.4.10 Specific Gravity and Shrinkage in Volume Tests

The specific gravity and shrinkage in volume tests consist of repeated weight and volume measurements conducted on samples of green wood as the wood is allowed to season. These measurements are used to determine the specific gravity of the wood, and the loss of volume encountered while seasoning. Specific gravity information is used to correct strength properties for variations in tree density from different forests and to develop strength limits for fasteners. Volumetric shrinkage results may be used to determine required cutting sizes in lumber production and to estimate performance and stresses present in structures due to moisture content changes (17).

4.4.10.1 ASTM Requirements

ASTM D143 provides specifications for the specific gravity and shrinkage in volume test, and requirements on the number and size of specimens needed (1). The test is conducted using 2 by 2 by 6 inch cubes taken from green specimen sticks. The actual dimensions are to be measured at the beginning of the test, and at several other times during the test.

The specimen is first weighed green, and the volume measured via immersion. Weight, volume, and measured dimensions are recorded for this green condition.

Samples are then piled loosely, and allowed to air season to approximately 12% moisture content. The samples are then weighed, measured, and the volume again determined by immersion.

Samples are placed in an oven, and dried at 103±2 °C until approximately constant weight is attained. Samples are weighed, and while still warm are immersed in a hot paraffin bath, to form a thin waterproof coating. The volume of the coated sample is then determined by immersion. ASTM recommends that volume determination by immersion be accomplished using a system which measures submerged buoyancy with an automatic balance.

Six specific gravity and shrinkage in volume specimens are to be selected per bolt, to give a ratio of one test near the pith to one test near the log periphery, to four tests from the average log section. With an average sample site yielding 16 bolts, ideally 96 samples would be tested. This test is only performed on the green wood.

4.4.10.2 Specific Gravity and Shrinkage Test Equipment

The equipment used for the specific gravity and shrinkage in volume test consists of a digital balance, a water bath, and a heavy weighing basket.

The digital balance used in this study is equipped with a hook on the underside of the case which allows the weighing basket to be hung from the balance. Once hung from the balance, the basket is suspended within a water bath. The basket submerges due to its own weight. This arrangement is shown in Figure 4.18.

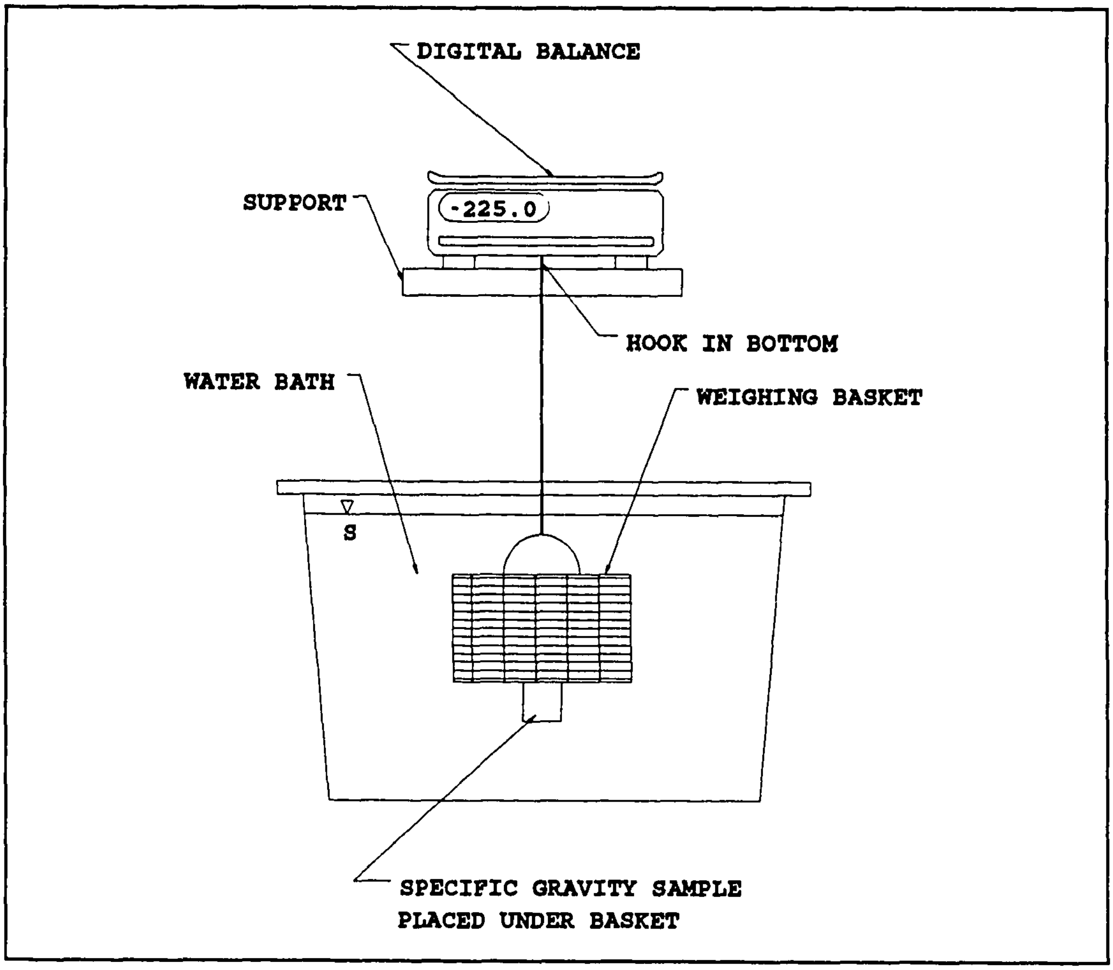

FIGURE 4.18: SPECIFIC GRAVITY APPARATUS

To determine the volume of the specimen, the digital balance is zeroed with the basket submerged in water. The sample is then placed beneath the weighing basket, such that its natural buoyancy attempts to lift the basket. This lifting force is equivalent to the amount of water displaced by the sample, minus the actual weight of the sample. The volume of the sample is given by the buoyant force plus the sample weight times the density of water, 1 gm/cm^3.

The same digital balance used to determine the volume of the samples is used to determine their weight, merely by placing the sample on the pan of the balance after zeroing it. It is not necessary to remove the submerged weighing basket, provided time is allowed for currents in the water bath to damp out. The balance used here displays weight in grams to the nearest .1 gram.

4.4.10.3 Specific Gravity and Shrinkage Test Procedures

Samples for the specific gravity and shrinkage in volume test are taken from stored green specimen sticks. These samples are table sawed to the required dimensions, and splinters or burrs removed with sanding equipment.

Measurements of dimensions, weight, and volume are made shortly after cutting the green sample, and are recorded on a prepared form. Samples are then loosely piled in an opened box, and allowed to season at room temperature for approximately eight weeks.

The series of measurements is repeated on the air seasoned samples. Samples are then placed in an oven for a day to remove the remaining moisture. As the samples are removed from the oven, they are weighed, and then quickly dipped in a hot paraffin bath to form a thin sealing film of wax.

Dimensions and volume measurements are then made for the final time. At this point, the recorded test measurements are entered into computerized spreadsheets for analysis. A total of 20 specimens were tested using this procedure. Data from these test measurements is presented in Appendix B. Analysis of the collected data is dealt with in Chapter 5.

4.4.11 Radial and Tangential Shrinkage Test

The radial and tangential shrinkage tests consist of a series of weight and length measurements made on specimens cut from logs such that the long axis of the sample corresponds to a line either tangent to or across (radial to) the directions of the annual growth rings. The weight and length measurements are repeated as the samples are allowed to season. These measurements are used to determine the shrinkage that is to be expected with change in moisture content in the species being studied.

4.4.11.1 ASTM Requirements

ASTM D143 provides specifications for the radial and tangential shrinkage tests, along with requirements for the number and type of specimens needed (1). The radial and tangential shrinkage determinations are to be made using 1 by 1 by 4 inch specimens oriented such that the major axis is either tangential to, or across (radial to) the annual growth rings of the timber sample. These samples are cut from waste produced during the initial log cutting process or from disks cut from the logs prior to cutting the sample sticks. In either case, the wood is to be taken from the d bolt, and if possible from the upper bolt of each pair of bolts taken from other heights of the tree. Care must be taken to insure the wood is green, and has not been affected by previous drying.

The shrinkage determinations are made by measuring the specimen length in the direction in which the shrinkage is to be determined. The specimens are weighed at the time of measurement. Specimens are then allowed to air dry, and the measurement procedure repeated. This is to be followed by oven drying at 103 ± 2°C until constant weight, at which point the measurements are repeated. Measurements are to be made to the nearest .001 inches, and weights are to be measured to not less than ±.2% of sample weight.

Shrinkage specimens are taken from each d bolt. For a normal sample site of five trees, there will be 5 d bolts. From each d bolt, four radial specimens, and four tangential specimens shall be obtained. Of each group of four specimens, two shall be from the heartwood, and two from the sapwood, consisting entirely of sapwood if possible. For an average sample site then, 20 specimens will be tested in radial shrinkage, and 20 in tangential shrinkage.

4.4.11.2 Radial and Tangential Shrinkage Test Procedure

Samples for the radial and tangential shrinkage tests are cut from disks collected during the initial sample collection procedure as described in 3.5.1. When collected, these disks had been sealed in plastic and then stored in the concrete curing room described in 3.5.3, and as such had not been subjected to drying.

The shrinkage samples were cut from the disks by first cutting strips from the disks using a bandsaw, and then table sawing the samples out of the strips. Due to the small diameter of the trees used in this study, it was not possible to cut all shrinkage samples to 4 inch lengths; several specimens 2 1/2 inches were cut to ensure obtaining adequate numbers of specimens. In all but the largest of disks, it was only possible to recover four tangential samples and three radial samples. To counter this, a total of eight disks were processed into shrinkage samples.

Specimens were measured while green with digital calipers to the limit of the calipers accuracy of .0005 inches. Sample weights were measured to the nearest .01 grams using a digital balance. Specimens were then allowed to air dry, with the measurement process repeated once during the air drying, and at the end of air drying. Specimens were then further dried for a day using an oven, and the final measurements taken. At this time the data was entered into a computer spreadsheet for data analysis.

A total of 22 specimens were tested in radial shrinkage, and a total of 32 in tangential shrinkage. Data for these tests is available in Appendix B. Analysis of the collected data will be dealt with in Chapter 5.

4.5 Moisture Content Determinations

The mechanical and shrinkage properties of wood vary with the moisture content of the wood (17). While efforts are taken to control the moisture content of the wood specimens being tested, as described in Section 3.5.3, there is some variation and it is necessary to determine the moisture content of the wood as tested to allow for correction of test results to a standardize moisture content level.

ASTM D143 provides specifications for the determination of moisture content in wood test specimens (1). The procedure involves weighing a cube cut from the tested specimen, drying the cube to constant weight in an oven, and weighing the cube again. The difference in weight is the water content of the wood. Dividing the water content by the weight of the dry cube yields the moisture content. In equation form this is:

$$\text{Moisture Content\%} = \frac{\text{Test Weight} - \text{Oven Dry Weight}}{\text{Oven Dry Weight}} \times 100 \qquad (4.1)$$

Moisture contents for the test procedures described above in Section 4.4 where performed as follows. Shortly after a test was performed, a section approximately 1 inch long is cut from the test specimen. These cubes are sealed individually into metal cans to limit moisture content changes prior to weighing the cubes. When several cubes have been acquired, the cubes are removed from the metal cans, and weighed, with the weights being marked on the cube. The cubes are baked in an oven at approximately 100°C for one to two days to drive out any moisture present. After baking, the cubes are weighed while still warm, and the dry weight marked on the cube. With the weights marked on the cube, the moisture content may be calculated at any time using the equation given above. The digital balance used to weigh the cubes will measure weight to the nearest .01 gram.

Moisture content data for test samples is entered into the spreadsheets used to prepare the test result reports printed out for every test specimen. Examples of these test reports may be found in Appendix A.

4.6 Permissible Variations

ASTM D143 provides limitations for the variation of measurements that are conducted during timber testing procedures (1). Additionally, ASTM D143 provides suggestions for the type of measurement equipment to be used.

Weights of test specimens and of moisture samples are to be determined to an accuracy of not less than ±.2%. Depending on the test being conducted the required accuracy varies from nearly ±2 grams for weighing the static beam samples to ±.04 grams for weighing the moisture samples. Section 4.4 of this report provides descriptions of the weighing equipment used in each test. In all cases, suitable equipment was used.

Dimensions of test specimens are to be measured to an accuracy of not less than ±.3%, except that in no case should the measurement be made to less than ±.01 inch. The required accuracy varies with the test being conducted from ±.01 inches for the length of the static beam specimens to ±.001 inches for measuring the cross section of the parallel tension tests. Section 4.4 of this report provides descriptions of the dimensional measuring equipment used. In all cases, equipment of suitable accuracy was used.

The testing machine speed used for a test procedure is not to vary by more than ±25% from the speed specified for that test. If the specified speed cannot be obtained, the testing speed is to be recorded on the test sheet. Specific information about the testing speeds used in this study is found with the descriptions of the test procedures given in Section 4.4. Testing speed of the MTS hydraulic testing system may be checked by timing the travel of the loading ram with a stopwatch while measuring the travel with a dial gauge or the LVDT integral to the MTS unit. This was done at the beginning of each test procedure to ensure the control software was written correctly, and not as an accuracy test. However, due to the closed loop feedback system used by the MTS unit, errors and variations in the testing speed can be expected to follow errors in the MTS displacement transducers. For the ±1 inch travel range this error is less than .3% and for the ±5 inch travel range is less than .4% The individual test descriptions given in Section 4.4 provide information regarding the specific travel ranges used. In all cases, testing speeds were suitably accurate.

CHAPTER 5: DATA ANALYSIS

5.1 Introduction

Approximately 1600 specimens were tested during this procedure, resulting in the creation of about 60 mb of data files stored on computer disk. These files contain the raw, unprocessed test data such as load and deflection data. The data in these files must be analyzed in order to obtain useful properties information.

The analysis procedure consists of two major parts. First, the mechanical property values for the individual test specimens must be determined using the raw test data. This is done by mathematical manipulation of the raw data files collected for each sample. Second, the indicator mechanical properties values must be determined for the wood species in general. The indicator properties are the 5% exclusion limit for strength properties, such as compressive strength or modulus of rupture, and the average value for stiffness properties such as modulus of elasticity. The indicator properties are obtained by statistical analysis of the data set comprised of the individual specimen test results.

Using principles from mechanics of materials, measured loads and deformations are converted into stresses and strains, which are then used to obtain mechanical properties for the individual test specimens. The details of the mathematical reduction of the data is addressed in Section 5.2.

American Society for Testing and Materials D2915, "Standard Practice for Evaluating Allowable Properties for Grades of Structural Lumber" provides guidelines for the analysis of the mechanical property data (5). In general, mean values and standard deviations are determined for the mechanical properties data sets using several probability distributions. Goodness-of-fit tests are conducted to verify the selected distributions, and the indicator properties are obtained for the wood species using the best distribution. Statistical analysis of mechanical property data sets is dealt with in Section 5.3.

5.2 Data Processing and Reduction

5.2.1 Test Results and Reports

The results of the individual mechanical properties tests described in Chapter 4 are each contained within pairs of data files created by the testing software described in Section 4.3.3. The first file of the pair contains the test results in the form of voltages measured by the data collection equipment; the second file contains the test results presented in terms of engineering units.

The files consist of a header block containing the input testing data, such as sample weight and physical dimensions, and a series of 4-tuples containing the real-time test data stored in a "comma and space separated variable" (CSV) file format. One of these 4-tuples is of the following form: <time increment, load, sample deformation, load ram position>. An example of the two types of data files is given in Appendix A. The CSV type file format used to create the data files allow the files to be loaded directly into a computer spreadsheet. This allows for convenient manipulation of the large data volumes that must be handled for timber strength determinations.

Various calculations are performed using the information in the data files to obtain the mechanical properties values for each specimen. These operations are described in Section 5.2.2. The results of these calculations are summarized in a report format. Each report contains the testing parameters, specimen dimension and characteristics, and the calculated mechanical property values. If modulus of elasticity is determined for the test being analyzed, a load versus deformation plot is included with the report. Examples of these reports and plots are contained in Appendix A.

The generated reports are printed to paper, and saved to computer disk. The reports saved on disk are collected together into data summaries given in Appendix B, and in this form are used for the statistical analysis of Section 5.3.

5.2.2 Mechanical Property Values

The types of mechanical properties to be obtained for a given test specimen vary with the test type. These mechanical properties include: modulus of elasticity, proportional limit, ultimate strength, modulus of rupture (ultimate bending strength), cleavage load, hardness load, nail withdrawal load, perpendicular bearing load, shrinkage, and specific gravity.

5.2.2.1 Modulus of Elasticity

Modulus of elasticity values may be calculated for four of the eleven mechanical tests described in Chapter 4. These tests are: static bending, compression parallel to grain, compression perpendicular to grain, and tension parallel to grain.

Modulus of elasticity, E, is defined as the ratio of stress, σ, to strain, ϵ, in a particular direction in a material (8) and has units of force per area.

$$E = \frac{\sigma}{\epsilon} \tag{5.1}$$

The modulus of elasticity in the linear region may be calculated by determining the slope of the linear portion of the line in a stress versus strain plot.

Data plots required by ASTM D143, however, are in the form of a load versus deformation curve. Such a plot is shown in Figure 5.1. Thus, modulus of elasticity deter-minations for timber purposes are performed by first determining the ratio of load, P, to deformation, Δ, and converting this ratio to σ/ϵ. Conversion is performed using the definitions of stress and strain:

$$\sigma = \frac{P}{A} \qquad \epsilon = \frac{\Delta}{L} \tag{5.2}$$

Where A is the loaded area, and L is the length over which Δ is measured.

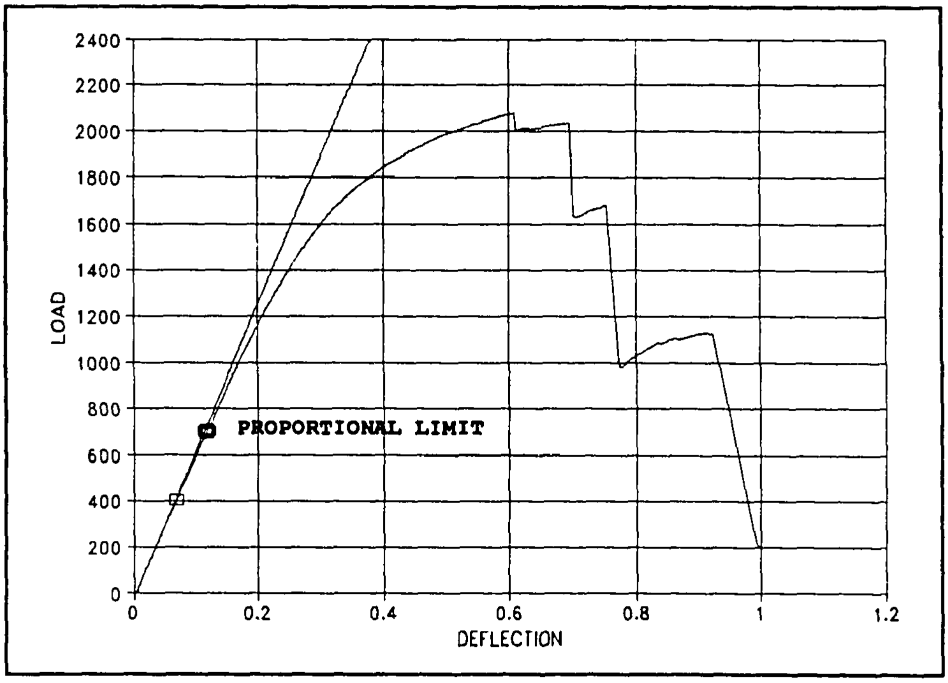

FIGURE 5.1: LOAD VERSUS DEFLECTION PLOT

The modulus of elasticity is then given by:

$$E = \left(\frac{P}{\Delta}\right) \times \left(\frac{L}{A}\right) \tag{5.3}$$

The ratio of P/Δ is not calculated directly, but rather is determined by use of linear regression upon part of the test data set. Referring to Figure 5.1, it is apparent that the initial portion of the plot is approximately linear; the modulus of elasticity is obtained in this region.

Examination of the data sets collected during the course of this project indicate that this linear region contains from 100 to 200 data points, which represents 1/3 to 1/2 of the data points for a given test. The first few data points contain some experimental noise, created by such things as sample movement in the test fixtures, lack of transducer sensitivity, or electrical noise in the first few seconds of a test. The last few points in the linear region begin to show deviation from a straight line. Using approximately 40 data points in the middle of the linear portion of the data set avoids these problems with the data at the ends of the linear region, and allows the slope of the region to be determined via linear regression.

The linear regression is carried out with a computer spreadsheet using a least-squares function which returns the slope of the line and a correlation coefficient. The operator has the option of specifying different data ranges via keyboard macros to attempt to obtain higher correlation coefficients. High correlation coefficients, and study of data plots produced using the regression procedure indicate the technique accurately determines the slope of the linear region, thus automating the determination of the modulus of elasticity.

A plot of load versus deformation, showing both the actual line created by the test data, and the best fit line created by the linear regression process is included with each test report, examples of which are given in Appendix A. It is uncommon for mechanical property test result plots to start at zero as the deflection measurement equipment used in a loading test is frequently less sensitive than the load traducers. As such, the best fit line is translated downward to zero in the plots to more accurately represent the initial deflection behavior. This practice is recommended by ASTM (1).

The modulus of elasticity for the static bending test must be calculated in a slightly different fashion than for compression tests, as the stresses are bending stresses and the measured deformations are bending deformations. The mechanics of materials expression for deflection of a simply supported beam with a point load at the center is (8):

$$\Delta = \frac{PL^3}{48EI} \tag{5.4}$$

Where I is the moment of inertia calculated from the cross sectional dimensions of the beam, and L is the span length of the beam. Equation 5.4 can be rearranged to yield the modulus of elasticity in terms of the P/Δ ratio:

$$E = \left(\frac{P}{\Delta}\right) \times \frac{L^3}{48I} \tag{5.5}$$

Note that the modulus of elasticity value obtained for the static bending test is a composite value reflecting the contributions of elastic effects, and shear effects. Thus, the modulus of elasticity calculated for a static beam is most correct for a specific span to length ratio; this ratio is 14:1 in the tests conducted here (5,17).

5.2.2.2 Proportional Limit

The proportional limit is the point at which the stresses in some object are no longer linearly proportional to the resulting strains. Figure 5.1 is a load versus deflection plot with the proportional limit indicated. The proportional limit is typically expressed in terms of the stress or load at the proportional limit. Proportional limits may be calculated for four of the nine mechanical tests described in Chapter 4. These tests are: static bending, compression parallel to grain, compression perpendicular to grain, and tension parallel to grain.

For the purposes of this study, the proportional limit is detected by comparison between the best fit line created by the linear regression procedure of Section 5.2.2.1 and the actual line created by plotting the data. When the difference between the two lines exceeds a selected error limit for at least two sequential data points, the point at which the error limit was exceeded is taken as the proportional limit.

This process is carried out automatically by the computer spreadsheet (e.g. Figure 5.1). Using the value of deflection attained at some data point, an expected load is calculated for that data point using the linear regression equation. This expected load is subtracted from the actual load measured at that deflection; if this difference exceeds the selected error limit, the point is recorded. If the next data point in sequence also exceeds the error limit, the previous load and deflection are recorded as being the values at the proportional limit. Two sequential error values are needed to separate chance occurrence from general trends. These data points may be seen on the sample data plots in Appendix A and in Figure 5.1; a light box on the plot indicates a point at which the error limit was exceeded, while a heavy box indicates the proportional limit.

The error limit level defining the divergence point is selected depending upon the inherent variability within the data sets due to such things as testing irregularity, electronic noise and other interference. Error limits used during this project range from 5 to 10 pounds depending on the type of test being studied and are a very small percentage of the total load at the proportional limit.

5.2.2.3 Ultimate Strength

Ultimate strength values may be calculated for five of the mechanical tests. These five tests are: compression parallel to grain, shear parallel to grain, cleavage, tension parallel to grain, and tension perpendicular to grain. While orientation of the forces and loaded areas varies in each test, the computation of the ultimate strength is similar. Modulus of rupture, which is an ultimate strength in bending requires special treatment and is dealt with separately in Section 5.2.2.4.

Ultimate strength, σ_μ, may be defined as the maximum strength attainable in a material in a particular property test. It has units of force per area. The particular test type is frequently used to describe the ultimate strength, as in compressive strength, shear strength, etc.

Ultimate strength is calculated by dividing the maximum load, P_{max}, by the loaded area, A:

$$\sigma_\mu = \frac{P_{max}}{A} \tag{5.6}$$

For the purposes of this report, maximum load, P_{max} is determined using a spreadsheet sort function to extract the maximum values from the list of all load data collected.

5.2.2.4 Modulus of Rupture

Modulus of rupture is calculated for the static bending test. The modulus of rupture, or ultimate bending strength is similar in usage to other ultimate strength values, but differs in that it is a composite strength value used to reflect the combination of tensile and compressive forces present in a bending beam, as wood has different strengths in compression and tension.

The modulus of rupture, MOR is based on the mechanics of materials expression for bending stress, σ_b, which assumes a linear stress distribution. The stress distribution in wood at failure is not linear; however, the mechanics of material expression may be used to approximate the actual behavior. The expression for bending stress in a linear material is given by:

$$\sigma_b = \frac{Mc}{I} \qquad \text{where } M = \frac{PL}{4} \tag{5.7}$$

Where M is the bending moment present in the beam; c is the distance from neutral axis to outer beam fiber (half of the beam depth in the linear-elastic case); I is the moment of inertia of the beam, calculated from section dimensions; P is the bending load; and L is the span length of the beam.

Based on equation 5.7, The modulus of rupture for wood is approximated as:

$$MOR = P_{\max}\frac{Lc}{4I} \tag{5.8}$$

Maximum bending load, P_{max} is determined here by using the spreadsheets sort functions to extract the maximum values from the list of all load data collected.

5.2.2.5 Other Mechanical Properties

Several other mechanical properties are generally determined when characterizing a wood species. These properties are found using the cleavage test, hardness test, nail withdrawal test, perpendicular compression test, radial and tangential shrinkage test, and the shrinkage in volume and specific gravity test.

The cleavage load is defined as the load required to split a test specimen, divided by the width of the surface the load acts over; the apparatus for this test is described in Section 4.4.6. Cleavage load has units of force, and requires no special procedure to calculate.

The hardness is defined as the load required to press a steel ball half of its diameter into a wooden surface, as described in Section 4.4.4, and has units of force. The hardness value is recorded directly, and requires no calculation.

The nail withdrawal load is defined as the maximum withdrawal force generated by extracting a nail driven into a wood specimen, as described in Section 4.4.9, and has units of force. The withdrawal load is recorded directly, and requires no calculation.

The perpendicular bearing stress limit is defined as the force required to imbed a standard test plate in a wooden sample to a depth of .1 inch, as described in Section 4.4.3. The perpendicular bearing stress limit has units of force per area. This stress limit is calculated using the procedures of Section 5.2.2.3, except that the load value used in the computation is that at .1 inch compression instead of P_{max}. This value is obtained by selecting the data point that is closest to .1 inch of penetration, and using the corresponding load. This is an approximation, but a very good one as the selected data point seldom varies more than .001 inch from the desired value of .1 inch.

Radial and tangential shrinkage are defined as the amount a green specimen shrinks in the radial and tangential directions as it is allowed to season. The shrinkage is determined by measuring the initial and final sizes of test specimens, as described in Section 4.4.11. The shrinkage is determined using equation 5.9:

$$SHRINKAGE,\% = \frac{L_{INITIAL} - L_{FINAL}}{L_{INITIAL}} \qquad (5.9)$$

Where L is the length of the specimen in either the radial of tangential directions, as appropriate to the specimen being measured.

Volumetric shrinkage is defined as the change in volume that occurs as a green specimen is allowed to season. Volumetric shrinkage is measured as part of the specific gravity determination described in Section 4.4.10. The volumetric shrinkage is calculated using equation 5.9, except that the initial and final volumes are used.

Specific Gravity is defined as the ratio of the density of a wood sample to the density of water; the density of the wood is given by its weight to volume ratio. The specific gravity of green wood and of seasoned wood are both measured using the test procedures given in Section 4.4.10. Wood scientists generally express the specific gravity as a function of the woods oven dry weight. Using $W_{OVENDRY}$ to indicate sample weight, and VOL to indicate the sample volume, the specific gravity, S.G. is given by equation 5.10:

$$S.G. = \frac{W_{OVENDRY}}{VOL} X \frac{1}{\gamma_{water}} \qquad (5.10)$$

γ_{water} is the density of water, in english units 62.4 lb/ft^3.

5.2.3 Moisture Content Corrections

The mechanical properties of wood vary greatly with respect to the moisture content of the wood being tested. In general, strength properties increase as the moisture content decreases once the moisture content drops below the fiber saturation point. The fiber saturation point is defined as the point at which no free liquid water remains in the cell cavities in the wood. Above the fiber saturation point, no change in strength properties occurs with change in moisture content. The determination of moisture content for wood test specimens is discussed in Section 4.5.

For comparison and/or design purposes, it is necessary to report the mechanical properties at standardized moisture contents. Wood scientist generally define the standard moisture contents as 12%, a value most wood equilibrates at under normal humidity, and "green", meaning any level of moisture content above the fiber saturation point. For structural engineering purposes, two ranges are used: at or below 19% moisture content, which is a moisture content easily obtained by air-drying, and less than 15 % moisture content for the case of kiln-dried wood used in dry service. In any case, it is desirable to be able to convert the mechanical properties for one moisture content to the properties at a second moisture content.

Previous research has shown that a linear relation exists between the natural logarithm of a timber strength property and its moisture content (17,18,36). This relationship allows the development of moisture content correction equations, several of which are available.

Two moisture content correction equations are used here. The first is recommended by the Forest Products Laboratory in their Wood Engineering Handbook (17). In its most general form, this correction is written as:

$$P_2 = P_1\left(\frac{P_1}{P_F}\right)^{\left(\frac{M_1 - M_2}{M_F - M_1}\right)} \tag{5.11}$$

Where P_1 and P_2 are the values of a property at moisture content M_1 and M_2, respectively. P_F is the property in the wood's green state, which occurs when the moisture content is above the fiber saturation point, M_F.

To use this formula, it is necessary to know the fiber saturation moisture content and the green strength properties for the species being considered. The Wood Engineering Handbook provides fiber saturation values for several species. For this project, the fiber saturation value for white spruce was estimated as 27 %, based on the values listed for both red and sitka spruces in the Wood Engineering Handbook; these values were both listed as 27%. Green strength values are available from the tests performed on green wood.

The second moisture content correction used here is provided in ASTM D2915, "Standard Practice for Evaluating Allowable Properties for Grades of Structural Lumber."(5)

This equation is:

$$P_2 = P_1\left(\frac{\alpha - \beta M_2}{\alpha - \beta M_1}\right) \tag{5.12}$$

Where P_1 and P_2 are the values of a property at moisture content M_1 and M_2, respectively. If the moisture content M_1 is greater than 22%, the value is taken as 22%. M_2 must be less than or equal to 22%. The variables α and β are moisture content constants given in the following table:

TABLE 5.1: ASTM MOISTURE CONTENT CORRECTION FACTORS

PROPERTY	α	β
Modulus of Elasticity	1.44	.0200
Bending Strength	1.75	.0333
Tensile Strength	1.75	.0333
Compressive Strength, Parallel to Grain	2.75	.0833
Shear Strength	1.33	.0167
Compressive Strength Perpendicular to Grain	1.00	0

This formula does not require knowledge of the fiber saturation point or the green wood properties, which makes it somewhat more convenient to use than equation 5.11. However, equation 5.12 does not necessarily represent the behavior trend in wood, as the equation is not a logarithmic function. Equation 5.12 is recommended for no more than a 5% change in moisture content (5). Equation 5.11 is the preferred formula for correcting moisture content data.

Equation 5.11 is used for all moisture content corrected data presented in Appendix B, except in the case of the values for tension parallel to grain in seasoned wood. As no parallel tension tests were performed on green wood (see Section 4.4.7.3), it is not possible to use equation 5.11 for correcting the strength properties of the seasoned wood in this test series, and as such, equation 5.12 was used.

5.2.4 Results of Data Processing

Tables containing the pertinent testing data for all test types and for all specimens tested are available in Appendix B. These tables contain all of the measured test data, such as sample dimensions, weight, sapwood content, etc. The tables also contain important test data values, such as maximum load sustained and deflection at max load. The tables also contain values for the moisture content of each sample at the time of the test.

The last several columns of each table contain mechanical property values calculated for the individual samples from the test data, using the techniques described in Sections 5.2.2.1 through 5.2.2.5. These values are used in the statistical analysis described in Section 5.3.

Note that the "exclusion flag column" indicates samples that were culled from the statistical analysis due to irregularities in the sample or the testing procedure. ASTM D143 requires that data resulting from samples that failed through visible defects, or exhibit failure patterns typical of hidden defects, be excluded from analysis. Data from improperly performed tests is also marked for exclusion. A flag value of "yes" indicates the specimen was excluded.

5.3 Statistical Analysis Procedures

5.3.1 Statistical Analysis Definitions

Two mechanical property indicator values commonly used in wood science and engineering are the 5% exclusion limit for strength properties, and the mean value for stiffness properties. These terms, and other related terms, are defined below. Statistical analysis of the mechanical property data sets was conducted for the purpose of obtaining these indicator values for each of the test types described in Chapter 4.

A probability density function (PDF) is a function which indicates the probability of a variable attaining a specified value. A plot of such a function is called a probability distribution, an example of which is shown in Figure 5.2. The total area under the plotted distribution has a value of 1.

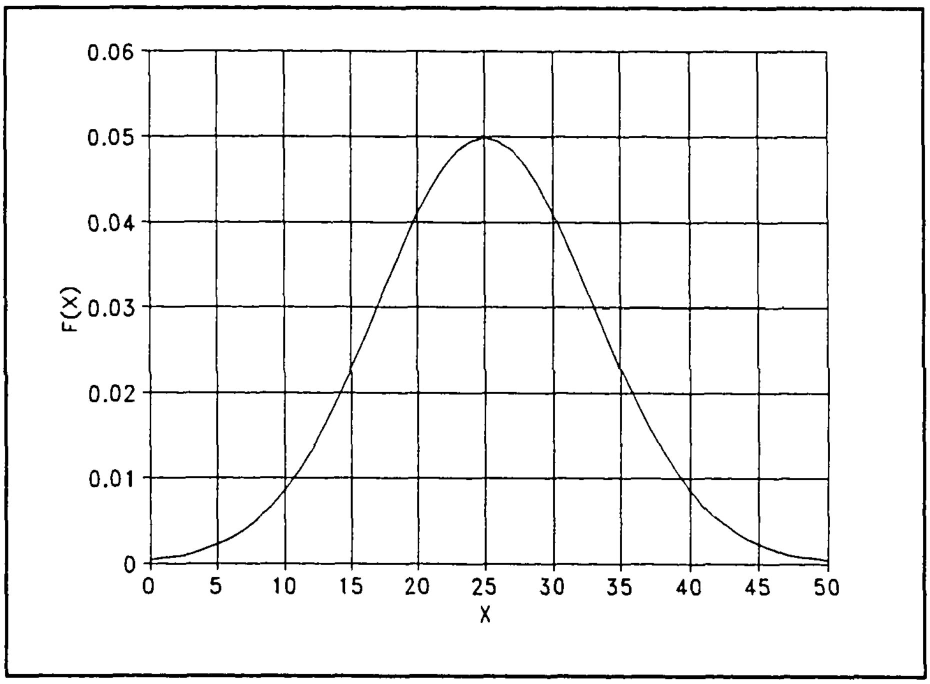

FIGURE 5.2: TYPICAL PROBABILITY DENSITY PLOT

The probability distribution may also be represented using the cumulative distribution function or CDF. This function represents the probability that the random variable is less than or equal to some given value (38). Three types of PDF's are used in this analysis, and one CDF, all of which are described in Section 5.3.3. A plot of a typical CDF is shown in Figure 5.3.

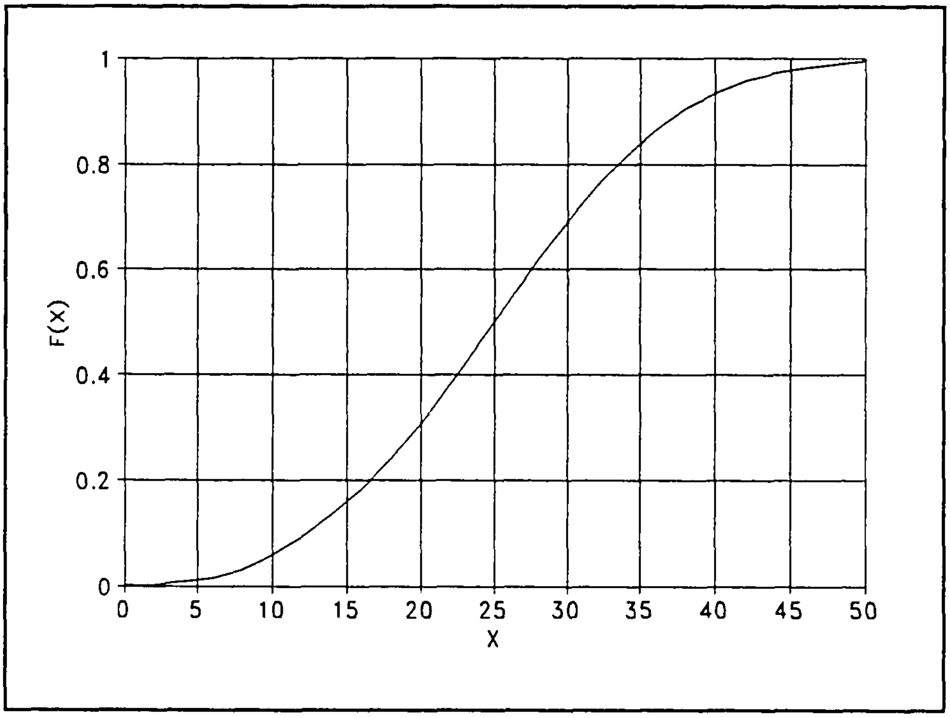

FIGURE 5.3: TYPICAL CUMULATIVE DISTRIBUTION PLOT

A histogram is a plot showing the number of occurrences of ranges of measured values within a data set (24). A histogram is a discrete approximation of a continuous probability density function. An example of a histogram is shown in Figure 5.4. A histogram is constructed by selecting uniform ranges of measured values, and then determining the number of values that fall within each range. The histogram may be normalized by dividing the number of occurrences by the sample size, in which case the histogram has units of percent.

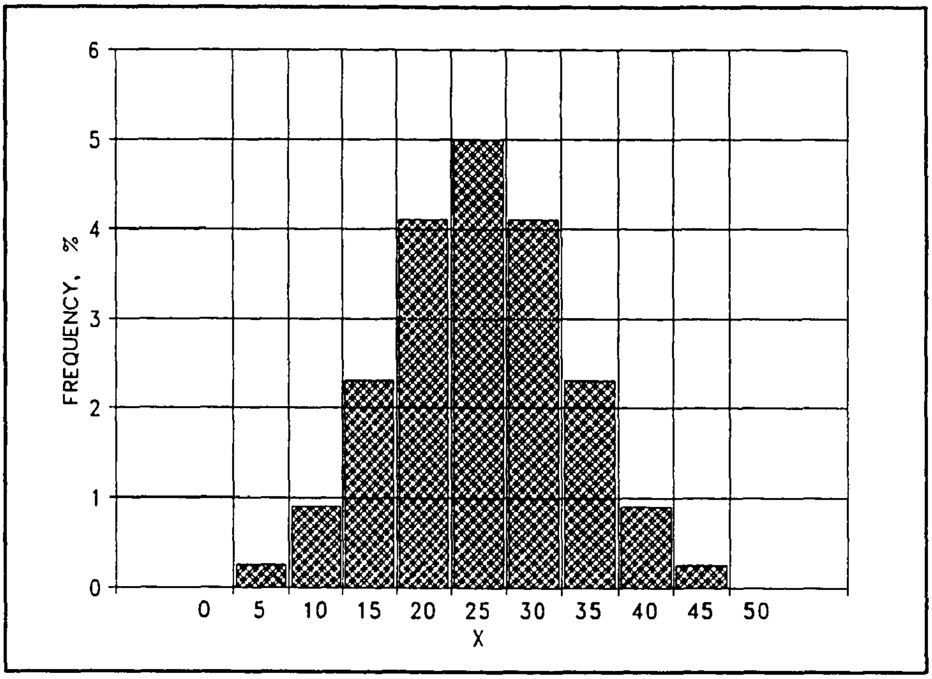

FIGURE 5.4: TYPICAL HISTOGRAM PLOT

Histograms are frequently used to demonstrate the degree-of-fit of a PDF to a given set of data by plotting the histogram and the PDF on the same graph. This is accomplished by multiplying the PDF by the area of the histogram. Note that the shape of the histogram may change substantially upon selecting new frequency ranges.

The mean value, μ, is the most expected value of a set of measurement data, and lies at the center of the area formed by a probability density function. In general, the mean value is the sum of the observations divided by the number of observations; however, methods of computation vary with the type of probability distribution being used. The mean value is one of the more commonly used statistics, and is often referred to as the sample average (38). Mean values are calculated for all mechanical properties investigated here, along with a "confidence interval" which is a range in which the mean can be expected to fall, given a certain desired confidence level.

The standard deviation, σ, provides an indication of the scatter or dispersion of the data, and is based on the differences between individual data points in a set and the sets mean value (24). The standard deviation is used in many types of PDF's as a shape defining parameter. The larger the value of σ, the more dispersed the data, and the flatter the distribution curve (24). The method used to calculate the standard deviation varies with the PDF being used. Standard deviations are calculated for all data sets investigated here.

The coefficient of variation, COV, is a dimensionless parameter defined by the ratio of σ/μ. This measure of variability facilitates comparison between the results of various mechanical tests, and between tests of different sample sites or species (18). Coefficients of variation are used with ASTM D2555 to combine test results from different test series to form composite property values.

The 5% exclusion limit is the value that 95% of the area of a probability distribution curve lies above; this is the value of the CDF at 5% (18,32). The 5% exclusion limit will be higher for data sets with less variability, that is lower standard deviations or coefficients of variation, even though the mean value of the data sets being compared is the same. This means that the more consistent a set of tests is, the more reliably that material's strength can be predicted. The 5% exclusion limit is most useful for strength properties such as compressive strength, although values are calculated for all data sets investigated here along with lower bound "confidence limits". The confidence limits indicate how low a value must be selected to know within a given certainty the 5% exclusion limit is being met.

5.3.2 ASTM Statistical Analysis Requirements

The intent of the statistical analysis procedures utilized for the study reported herein is to obtain 5% exclusion limits and mean values for the clear wood material properties of the tested Alaskan White Spruce. Requirements for the statistical analysis of timber data are found in ASTM D2915, "Standard Practice for Evaluating Allowable Properties for Grades of Structural Lumber."

The first requirement for statistical analysis is the correction of the mechanical properties for the individual specimens to standard moisture content levels. This procedure is discussed in Section 5.2.3. The two standardized moisture contents used here are 12% for seasoned lumber, and "green", meaning greater than 27% for unseasoned lumber.

Once corrected to standardized moisture contents, the sample means and standard deviations are to be calculated. From these values the confidence interval about the mean is also to be calculated.

ASTM D2915 requires that the sample 5% exclusion limit is to be determined, but does not specify procedures; rather D2915 states that procedures "adequate for the method adopted" be used. The lower tolerance limits for the exclusion limit are also to be determined by "adequate methods."

ASTM D2915 further requires that histograms be presented, regardless of the techniques used to analyze the data sets. If these techniques are parametric (probability distribution dependant), the probability density functions are to be verified as being suitable for use with the given data set using a goodness-of-fit test. As an option, the histograms may be drawn with the probability density functions superimposed to demonstrate adequacy of fit.

Lastly, D2915 requires that the allowable material properties for the clear wood be determined. The allowable value for modulus of elasticity shall be take as the sample mean, provided the width of the confidence interval is a sufficiently small fraction of the mean. That is, the interval divided by the sample mean is to be in the range of 0.01 to 0.1.

The allowable value for a stress property shall be taken as the sample 5% exclusion limit, provided the difference between the exclusion limit (E.L.) and the lower tolerance limit (L.L.) is a sufficiently small fraction of the 5% exclusion limit. That is, (E.L. - L.L)/E.L. is to be in the range of 0.01 to 0.1.

The exclusion limits and mean values can be used to obtain design values for Alaskan White Spruce using procedures specified by ASTM in Document D2555 "Standard Test Methods for Establishing Clear Wood Strength Values", and Document D245 "Standard Practice for Establishing Structural Grades and Related Properties for Visually Graded Lumber." Document D2555 presents techniques for combining strength values from separate test sites or from different species into composite values, while Document D245 specifies the corrections to be applied to timber to account for the presence of defects.

5.3.3 Probability Distributions

To meet the requirements of ASTM Document D2915, three probability distributions commonly applied to wood test results (12) are used. These distributions are the normal, the log-normal, and the Weibull distribution, each of which has its own defining parameters.

5.3.3.1 Normal Probability Distribution

The normal distribution has been extensively used for fitting experimental data on the properties of wood (12), and many other variables representing natural phenomena. The normal distribution is a symmetric, continuous distribution, whose range may encompass all real numbers (38). These features occasionally make the normal distribution a poor choice for mechanical properties test results, as the test results are always positive, and often skewed (12).

Two parameters define the normal distribution; these are the mean, μ, and the standard deviation, σ. The distribution is centered about the mean, while the height of the curve is controlled by the standard deviation. Examples of normal distributions with μ=0 are shown in Figure 5.5 with various standard deviations. The larger the standard deviation, the greater the variability (and COV) and the flatter the curves.

Using x to represent some value, and f(x) to represent the probability of the variable attaining that value, the probability density function is written as (24):

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(x-\mu)^2}{2\sigma^2}} \tag{5.13}$$

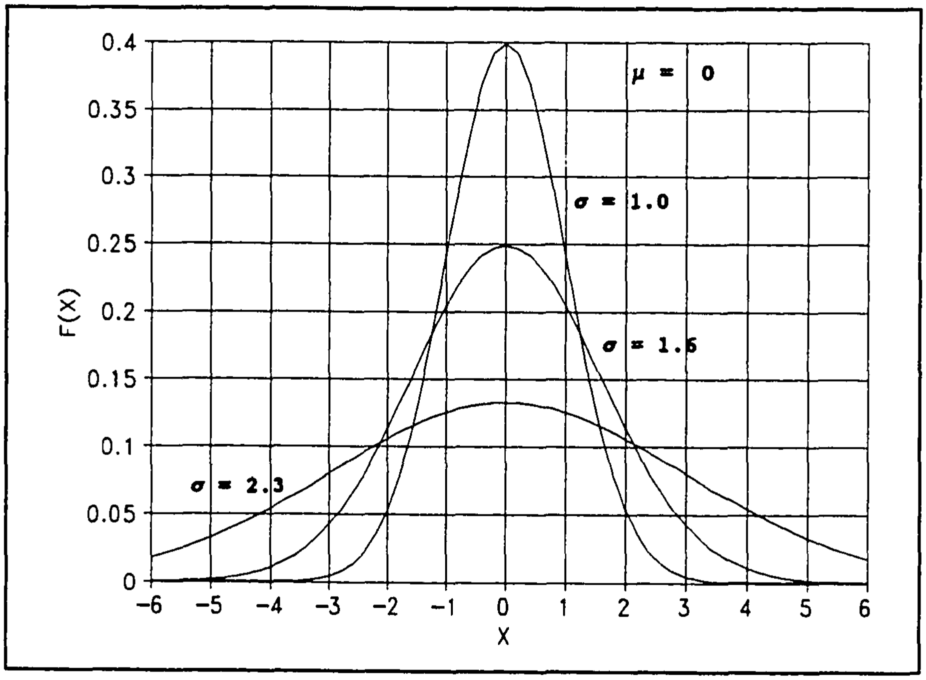

FIGURE 5.5: TYPICAL NORMAL PROBABILITY DISTRIBUTIONS

The distribution mean and standard deviation of the normal distribution are the same as the sample mean and standard deviation. These are given by:

$$MEAN,\ \mu = \frac{\sum_{i=1}^{n} X_i}{n}$$

$$STANDARD\ DEVIATION,\ \sigma = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \mu)^2}{n-1}} \tag{5.14}$$

where X_i is an individual sample value, and n is the number of samples in the set.

The cumulative distribution function (CDF) for the normal distribution is the integral of equation 5.13 (7). This integral is not generally convenient to use, however, the CDF is well tabulated, so determining the areas under the curve is not difficult. Using a table of areas (24,28), the 5% exclusion limit for the normal distribution is found as:

$$5\%E.L. = \mu - 1.645\sigma \tag{5.15}$$

which is the expression recommended by the Forest Products Laboratory (16).

5.3.3.2 Log-Normal Distribution

The log-normal distribution fits data sets of random variables whose logarithm is normally distributed. Because of the properties of the log function, the log-normal distribution is not symmetrical, and is always positive. This allows the distribution to more closely resemble material test results, which are always positive, and frequently skewed(10).

Two types of log-normal distribution are available, these being the two parameter and the three parameter distribution. These distributions are identical, except for the inclusion of a location parameter in the later. The location parameter serves to shift the location of the data, should the data set start at some other value than zero. As zero strength is a possible value in materials testing, however unlikely, the distribution should start at zero. Thus, the two parameter log-normal distribution is used here. Another advantage of the two parameter distribution is that the parameters may be calculated directly (12).

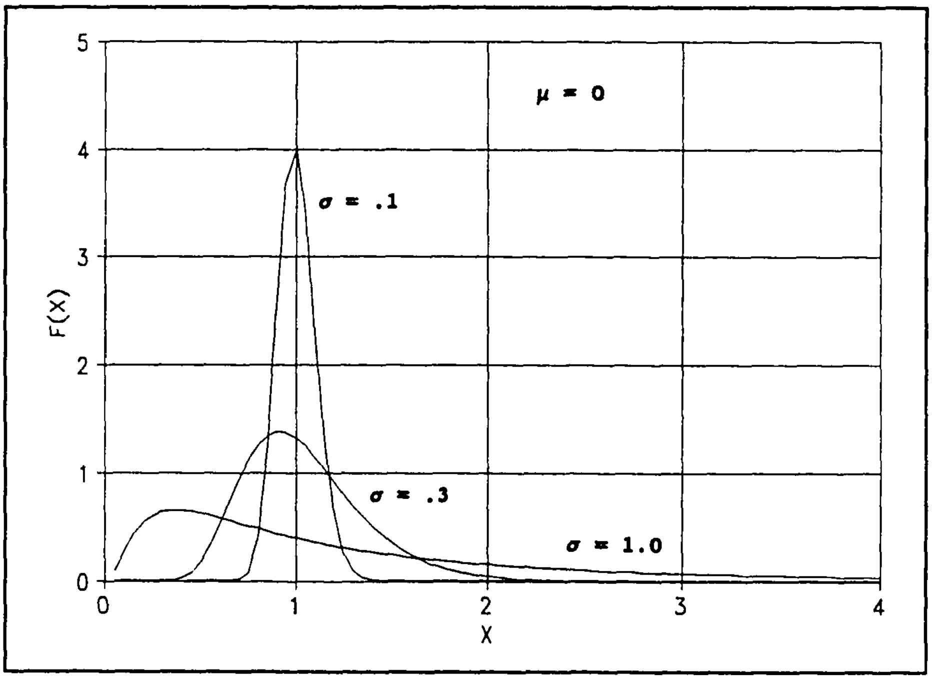

FIGURE 5.6: TYPICAL LOG NORMAL DISTRIBUTIONS

The two parameters used in the distribution are the mean of the logarithms of the data set, α, and the standard deviation of the logarithms, β as is given in equation 5.16 (12). The α parameter defines the location of the distribution's area centroid, while the β parameter defines the curves height and skew. Examples of several log-normal distributions with differing standard deviations are shown in Figure 5.6. The parameters, α and β, are given by:

$$MEAN\ Ln(x),\quad \alpha = \frac{\sum_{i=1}^{n} \ln x_i}{n} \qquad (5.16)$$

$$STANDARD\ DEVIATION.\ Ln(x),\quad \beta = \sqrt{\frac{\sum_{i=1}^{n} (\ln x_i - \alpha)^2}{n-1}}$$

Using x to represent a random variable, the probability of the random variable attaining a given value is f(x). The log-normal probability density function is (10):

$$f(x) = \frac{1}{\beta x\sqrt{2\pi}} e^{\frac{-(\ln x-\alpha)^2}{2\beta^2}} \tag{5.17}$$

The log-normal distribution mean and standard deviation are functions of the α and β parameters, and are given by:

$$\begin{aligned} L.N.\ DIST.\ MEAN &= e^{\left(\alpha + \frac{\beta^2}{2}\right)} \\ L.N.\ DIST.\ STD.\ DEV. &= \sqrt{\left(e^{(2\alpha + \beta^2)}\right)\left(e^{(\beta^2 - 1)}\right)} \end{aligned} \tag{5.18}$$

The CDF of the log normal distribution consists of the integral of equation 5.17. However, as the log-normal distribution is derived from the normal distribution, tables for the normal CDF may be used on the logarithm normalized data (7). The 5% exclusion limit is then found as:

$$L.N.\ DIST.\ 5\%\ E.L. = e^{(\alpha-1.645\beta)} \tag{5.19}$$

5.3.3.3 Weibull Distribution

The Weibull distribution has been used in the past to create failure and fatigue life models, and in recent years for wood property models (12,38). It is a flexible distribution which accommodates skewed data without transformation.

Three parameters are used in the Weibull distribution. The location parameter, ϵ (not strain), determines the position of the distribution on the independent axis. The shape parameter, k, determines the shape of the distribution; values less than 1 indicate an exponential type shape, values near 2 resemble the log-normal distributions, while higher values approach the normal distribution. The scaling factor, ω, determines the height of the distribution and the spread of the data. Figure 5.7 shows typical Weibull distributions for various values of k.

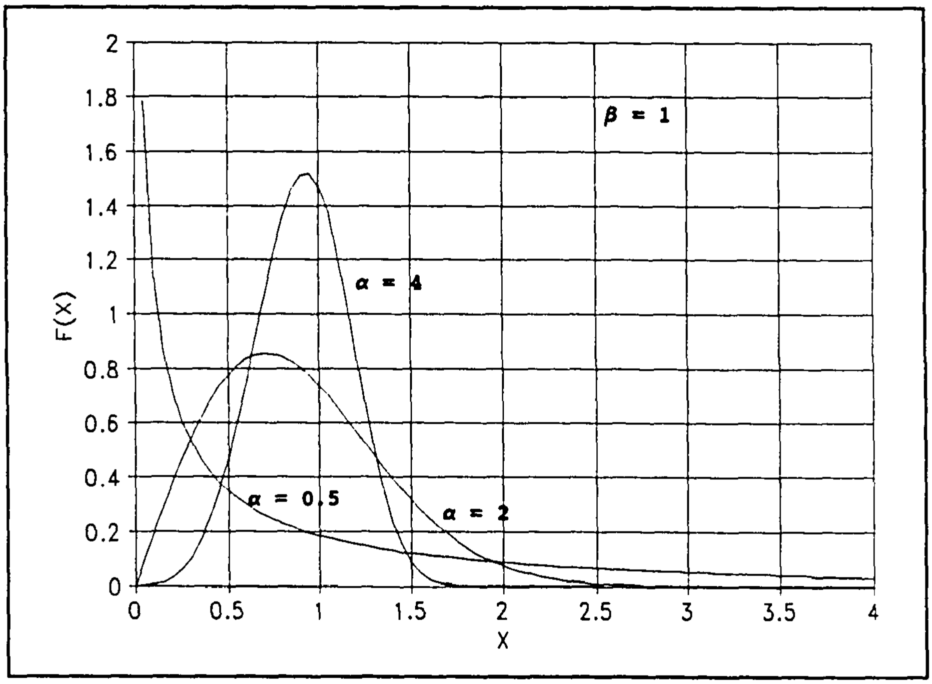

FIGURE 5.7: TYPICAL WEIBULL DISTRIBUTIONS

Unfortunately, the Weibull parameters are difficult to determine (12). Polynomial approximations for the parameters based on the mean and standard deviation of the data set are available. Such approximations are given by Peyrot and Aznavour in Sjaardema et. al. (31):

$$\epsilon = MINIMUM\ VALUE\ OF\ X \tag{5.20}$$

$$V = \frac{\sigma}{\mu - \epsilon} \tag{5.21}$$

$$K = \left(\frac{1}{V}\right)\left(1 + \frac{(1 - 4.92V(1 - 1.965059V(1 - .74199V)))}{(3.5697(1 - 2.48368V(1 - 1.02186V)))}\right) \tag{5.22}$$

$$\omega = \frac{\mu - \epsilon}{\Gamma\left(1 + \frac{1}{K}\right)} \tag{5.23}$$

Notice that equation 5.23 requires the use of the gamma function. This function is given in equation 5.24. The gamma function is also tabulated in many math texts.

$$\Gamma(x) = \int_0^\infty t^{x-1}e^{-t}dt \tag{5.24}$$

Using x to represent some value and f(x) to represent the probability of attaining that value, the Weibull probability distribution function is given by (12,38):

$$f(x) = \frac{K}{\omega}\left(\frac{x - \epsilon}{\omega}\right)^{K - 1} e^{-\left(\frac{x - \epsilon}{\omega}\right)^K} \tag{5.25}$$

The Weibull distribution mean and standard deviation are functions of the Weibull parameters, and require the use of the gamma function. They are given by:

$$WIEBULL\ DIST.\ MEAN = \epsilon + \omega\Gamma\left(1 + \frac{1}{K}\right)$$
$$WIEBULL\ DIST.\ STD.\ DEV. = \sqrt{\omega^2\left(\Gamma\left(1 + \frac{2}{K}\right) - \Gamma^2\left(1 + \frac{1}{K}\right)\right)} \tag{5.26}$$

The Weibull distribution has a closed form solution for the CDF, which simplifies the determination of the 5% exclusion limit. The CDF, and its inverse are given by (31):

$$f(x) = 1 - e^{\left(\frac{x - \epsilon}{\omega}\right)^K}$$
$$AND$$
$$x = \epsilon + \omega(-\ln(1 - f(x)))^{\frac{1}{K}} \tag{5.27}$$

To find the 5% exclusion limit, the inverse CDF of equation 5.27 is used, setting f(x) equal to 5%.

5.3.4 χ^2 Goodness-of-Fit Test

In order to meet ASTM Document D 2915 requirements for determining the accuracy of the probability distributions, it is necessary to conduct a goodness-of-fit test. Such tests compare the actual occurrence rates of values within a histogram with the occurrence rate predicted by the probability distribution. The greater the difference between the actual and the predicted values, the poorer the fit, and the less appropriate the distribution.

The test used here is the chi-square test, represented by the symbol χ^2. This is a common goodness-of-fit test and is based on the chi-square distribution, with n-1 degrees of freedom for determinant models with known parameters. Each data point in a set is a degree of freedom. For theoretical models with unknown parameters, n is to be reduced by 1 for every unknown parameter. With this is mind, if a particular distribution meets the requirements of equation 5.28 (7):

$$\sum_{i=1}^{k} \frac{(n_i - e_i)^2}{e_i} < C_{1-\alpha,f} \tag{5.28}$$

the distribution is an acceptable model at the significance level, α. Otherwise, the distribution is an inadequate fit, and should not be used as a distribution at that significance level. In the equation, n represents the observed frequencies, and e represents the frequencies predicted by the distribution. The quantity $C_{1-\alpha,f}$ is the value of the χ^2 distribution at the cumulative probability $1-\alpha$, at a significance level, α. The value of $C_{1-\alpha,f}$ is available from texts on statistics, and in particular Natrella (28). For a significance level of 90%, several values of $C_{1-\alpha,f}$ are given in Table 5.2.

If the summation calculated in equation 5.28 is less than the appropriate quantity from Table 5.2, no statistically significant difference exists between the expected and observed frequencies, and the distribution is a good fit (12). The lower the value of the summation, the better the fit of the distribution; this is used to select the best distribution when more than one distribution is being investigated is used.

TABLE 5.2: χ^2 VALUES AT 90% SIGNIFICANCE

n_f	$C_{1-\alpha}$	n_f	$C_{1-\alpha}$
16	9.31	30	20.60
18	10.86	40	29.05
20	12.44	60	46.46
24	15.66	120	100.6

It is important to note that while a probability distribution is a continuous function, a goodness-of-fit test is conducted using discrete increments for the sample data, as in a histogram. Thus, while the distribution may fit the data quite well, the value of the summation in equation 5.28 will vary with the "quality" of the histogram the distribution is checked against.

Also of interest is the fact that the χ^2 test is much more sensitive to data near the extremes of the distribution; a value near the edge of the distribution, with an occurrence frequency of 1% will generate a large test value if the distribution indicates the frequency should be near zero. A large frequency difference near the middle of the distribution has much less effect.

5.3.5 Confidence Intervals and Limits

ASTM D2915, in addition to requiring the determination of mean values and 5% exclusion limits for the data sets requires that these values be bounded in some manner to indicate the statistical reliability of the indicator values. This bounding is done by developing a confidence interval for the mean, and a lower confidence limit for the 5% exclusion limit.

The confidence interval for the mean provides an interval in which the mean value can be expected to fall with a given confidence level. The width of this interval is dependant upon sample size, n, standard deviation, σ, and a term called the t statistic, which is selected according to sample size and desired confidence level. Tables of the t statistic are available in ASTM D2915 and statistic text books (5,28). Using these terms, the confidence interval, CI, about the mean is given by (5,28):

$$CI = \mu \pm \frac{t\sigma}{\sqrt{n}} \tag{5.29}$$

For a confidence interval of 95%, several values of the t statistic are found in Table 5.3:

TABLE 5.3: VALUES OF THE T STATISTIC, CI=95%

SAMPLE SIZE	$t_{.95}$	SAMPLE SIZE	$t_{.95}$
20	2.086	50	2.011
25	2.060	60	2.000
30	2.042	120	1.980
35	2.031	∞	1.960

The lower confidence limit places a bound on the 5% exclusion limit. The limit is a value above which the 5% exclusion limit (5% E.L.) can be expected to fall with a specified confidence. It is calculated in a manner similar to equation 5.29, except that it is a one sided interval, and uses a term called the k statistic (28):

$$L.L. = 5\%\ E.L. - \frac{k\sigma}{\sqrt{n}} \tag{5.30}$$

Several values of the k statistic for a confidence limit of 75% are given in Table 5.4 (28).

TABLE 5.4: VALUES OF THE K STATISTIC, LL = 75%

SAMPLE SIZE	K_{75}	SAMPLE SIZE	K_{75}
23	1.907	35	1.849
24	1.901	40	1.834
25	1.895	45	1.821
30	1.869	50	1.811

Note that both of these confidence limit techniques are based upon an assumption of a normally distributed data set. Thus, the confidence limit techniques are only applicable to the mean value and 5% exclusion limit obtained from the normal and log-normal distributions.

5.4 Results of Statistical Analysis

Using the procedures and formulations presented in Section 5.3, the statistical analysis of the individual sample mechanical property values obtained in Section 5.2 was accomplished. This was done to meet ASTM requirements for the determination of the indicator values.

For each test procedure, and for each of the two standard moisture content levels considered, a histogram plot was created as required by ASTM D2915. Effort was taken to select a bar width for each histogram which provided the most continuous histogram possible. The histogram plots are overlaid with the three probability distributions used for the parametric analysis of the mechanical properties. In most cases, all three distributions closely resemble the histogram.

An example of the histogram plot with superimposed probability density functions is presented here as Figure 5.8. Individual plots for each of the test groups analyzed are presented in Appendix C. These plots serve as a visual indication of the appropriateness of the distributions for the fitted data set.

Goodness-of-fit tests using the χ^2 test described in Section 5.3.4 were conducted as required by ASTM D2915. For all test data sets, at least one of the distributions fit reasonable well, and in most cases all of the distributions fit.

Using the distributions, the indicator values of mean and 5% exclusion limit were calculated for the mechanical properties. The 95% confidence intervals about the mean and the one sided lower 75% confidence limit for the 5% exclusion limit were also calculated. In all cases the intervals and limits were sufficiently narrow to meet ASTM requirements for the determination of timber strength property values, as described in Section 5.3.2.

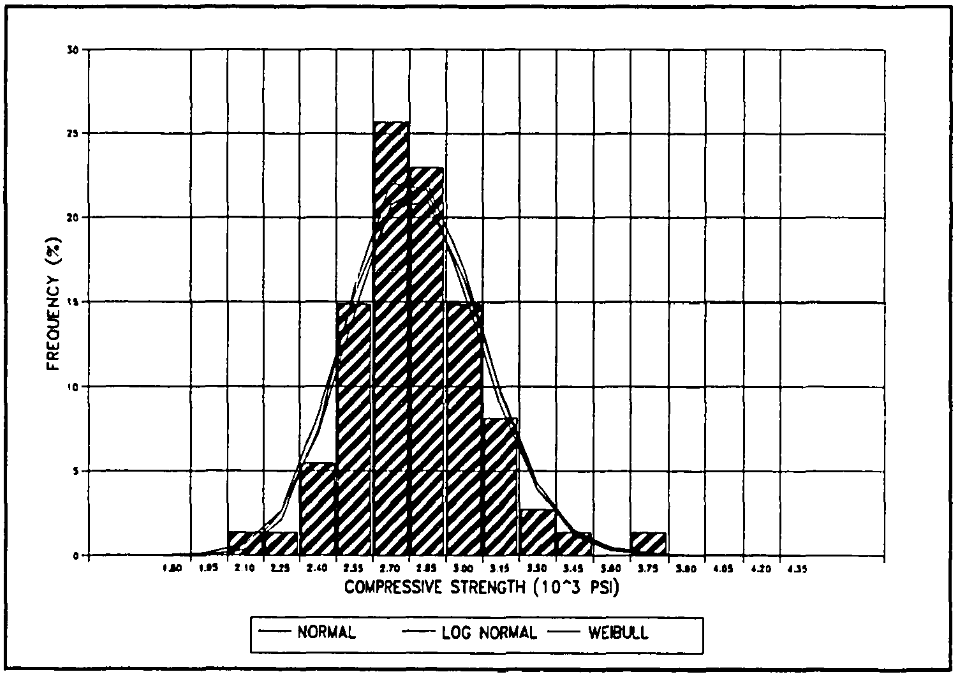

FIGURE 5.8: TYPICAL HISTOGRAM PLOT WITH SUPERIMPOSED PDF'S

Basic summaries of the results of the statistical analysis are tabulated in Tables 5.5 and 5.6. These tables contain the mean value, standard deviation, and 5% exclusion limit for mechanical properties of Alaskan White Spruce as calculated using the three distributions. Table 5.5 contains the results for green wood, while Table 5.6 contains the results for seasoned wood.

Appendix D contains a more detailed presentation of the statistical analysis results. The tables in Appendix D contain the mean value, standard deviation, and 5% exclusion limits, along with the confidence intervals and limits for the mechanical properties. The tables give the pertinent distribution statistics such as sample size and the results of the χ^2 fit test. The coefficients of variation are also given.

TABLE 5.5: MECHANICAL PROPERTIES OF ALASKAN WHITE SPRUCE (GREEN WOOD)

TEST TYPE	UNITS	NORMAL DISTRIBUTION			LOG NORMAL DISTRIBUTION			WEIBULL DISTRIBUTION		
		MEAN	STANDARD DEVIATION	5% EXCLUSION	MEAN	STANDARD DEVIATION	5% EXCLUSION	MEAN	STANDARD DEVIATION	5% EXCLUSION
STATIC BENDING										
MODULUS OF RUPTURE	(PSI)	5281.8	494.2	4468.8	5281.8	492.1	4513.1	5281.8	493.4	4495.9
MODULUS OF ELASTICITY	(PSI)	1180053	136119	956137	1180087	137174	968800	1180053	211542	973524
PARALLEL COMPRESSION										
COMPRESSIVE STRENGTH	(PSI)	2802.3	267.7	2631.8	2802.2	266.0	2387.2	2802.3	267.8	2374.1
MODULUS OF ELASTICITY	(PSI)	1287293	320823	759540	1291615	370098	782196	1287293	319787	795484
PERPEND. COMPRESSION										
STRESS AT P.L.	(PSI)	241.3	43.7	169.4	241.3	42.3	178.4	241.3	44.4	178.3
STRESS AT .04"	(PSI)	381.5	55.2	290.6	381.5	55.0	298.2	381.5	55.7	301.8
MODULUS OF ELASTICITY	(PSI)	25333	5302	16611	25330	5278	17666	25333	4953	18135
PARALLEL TENSION										
TENSILE STRENGTH	(PSI)	---	---	---	---	---	---	---	---	---
MODULUS OF ELASTICITY	(PSI)	---	---	---	---	---	---	---	---	---
SHEAR STRENGTH (AVERAGE)	(PSI)	484.4	68.9	371.0	484.5	69.9	378.7	474.4	69.5	384.8
PERP. TENSILE STRENGTH	(PSI)	299.2	57.3	204.9	299.2	57.8	214.4	299.2	59.8	221.5
CLEAVAGE LOAD PER INCH	(LBS)	141.3	11.4	122.5	141.3	11.5	123.2	141.3	11.4	123.9
HARDNESS										
RAD AND TAN AVG.	(LBS)	320.6	48.1	241.4	320.7	49.0	246.9	320.6	48.0	246.3
END	(LBS)	356.7	38.3	293.6	356.7	38.5	297.0	356.7	38.7	301.7
NAIL WITHDRAWAL										
RAD AND TAN AVG.	(LBS)	109.1	18.3	79.0	109.1	17.8	82.4	109.1	18.7	83.5
END	(LBS)	51.5	9.6	35.6	51.4	8.9	38.3	51.5	12.1	40.3
SHRINKAGE										
VOLUMETRIC	(%)	11.9	1.4	9.69	11.9	1.4	9.82	11.9	1.4	10.06
RADIAL	(%)	4.67	.60	3.69	4.67	.61	3.74	4.67	.60	3.77
TANGENTIAL	(%)	7.58	.72	6.41	7.58	.72	6.41	7.58	.72	6.41
SPECIFIC GRAVITY		.369	.023	.331	.369	.024	.331	.369	.027	.340

TABLE 5.6: MECHANICAL PROPERTIES OF ALASKAN WHITE SPRUCE (M.C. = 12%)

TEST TYPE	UNITS	NORMAL DISTRIBUTION			LOG NORMAL DISTRIBUTION			WEIBULL DISTRIBUTION		
		MEAN	STANDARD DEVIATION	5% EXCLUSION	MEAN	STANDARD DEVIATION	5% EXCLUSION	MEAN	STANDARD DEVIATION	5% EXCLUSION
STATIC BENDING										
MODULUS OF RUPTURE	(PSI)	9507.0	1003.3	7754.4	9506.4	989.0	7971.7	9507.0	1026.0	8071.0
MODULUS OF ELASTICITY	(PSI)	1513632	218143	1154786	1514124	1170630	1152936	1513632	216775	11638760
PARALLEL COMPRESSION										
COMPRESSIVE STRENGTH	(PSI)	6324.6	525.5	5460.1	6324.4	519.1	5508.3	6324.6	527.0	5561.0
MODULUS OF ELASTICITY	(PSI)	1767075	243928	1380619	1767404	241770	1399701	1767075	232868	13801040
PERPEND. COMPRESSION										
STRESS AT P.L.	(PSI)	462.5	65.5	354.7	462.5	66.1	362.4	462.5	66.7	363.6
STRESS AT .04"	(PSI)	725.5	95.7	567.9	725.5	97.9	576.5	725.4	76.7	585.7
MODULUS OF ELASTICITY	(PSI)	46872	7761	34106	46880	7929	35065	46872	8686	35604
PARALLEL TENSION										
TENSILE STRENGTH	(PSI)	13154.2	2859.9	8449.7	13153.8	2859.5	9026.3	13154.2	2938.0	9185.0
MODULUS OF ELASTICITY	(PSI)	1759821	262136	1328608	1760127	268986	1355134	1759821	263064	13716390
SHEAR STRENGTH (AVERAGE)	(PSI)	776.0	112.3	591.2	776.1	115.8	601.4	776.0	112.4	607.5
PERP. TENSILE STRENGTH	(PSI)	396.1	87.2	252.8	396.7	94.1	262.7	396.1	86.9	256.6
CLEAVAGE LOAD PER INCH	(LBS)	223.0	23.4	184.5	223.0	23.6	186.4	223.0	23.4	187.8
HARDNESS										
RAD AND TAN AVG.	(LBS)	467.1	51.8	381.9	467.0	50.5	388.9	467.1	52.8	393.5
END	(LBS)	549.9	47.7	471.4	549.9	47.2	475.9	549.9	49.3	480.1
NAIL WITHDRAWAL										
RAD AND TAN AVG.	(LBS)	90.5	19.9	57.8	90.4	18.8	63.1	90.5	22.9	65.9
END	(LBS)	52.5	13.9	29.7	52.4	13.4	33.6	52.5	14.8	34.1
SHRINKAGE										
VOLUMETRIC	(%)	---	---	---	---	---	---	---	---	---
RADIAL	(%)	---	---	---	---	---	---	---	---	---
TANGENTIAL	(%)	---	---	---	---	---	---	---	---	---
SPECIFIC GRAVITY		.418	.031	.367	.418	.031	.369	.418	.032	.375

5.5 Determination of Design Values

The values given in Tables 5.5 and 5.6 and in Appendix D are mechanical property values for clear, defect free Alaskan White Spruce. These values must be corrected for the presence of defects such as knots, checks, splits, and sloping grain in order to create design values usable for engineering purposes. Corrections must also be used for non-defect type factors such as moisture content, size, and duration of loading, as all of these factors effect the usable strength.

Design values are obtained by applying a stress ratio to the clear wood values. A stress ratio represents the difference in strength between a timber consisting entirely of clear wood, and one containing real-world defects. Stress ratios are developed using empirical and/or theoretical relationships between size of defect and strength loss.

Note that the design values obtained by using the stress ratios apply only to common uses of wood materials. Further design value modifications may be necessary if it is desired to use wood in situations which might adversely affect its behavior, including extremes of temperature, wet use applications, and other conditions of use. Such situations are dealt with in the National Design Specification for Wood Construction (26,27).

5.5.1 ASTM D245

American Society for Testing and Materials Document D245, titled "Standard Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Timbers" (4) is currently approved by the American Lumber Standards Committee (ALSC) for the purpose of developing stress ratios to be used in correcting clear wood strength data (29,41). ASTM D245 provides definition, methodologies, and formulations necessary to develop allowable design properties for visually graded lumber.

To meet ASTM requirements, visual grading of lumber is to be performed by an examination of all four faces and ends of a piece of lumber. During this examination the size and location of knots and other timber defects is to be determined. Individual pieces are sorted into "grades" based upon this visual inspection, and into categories based on the intended use of the pieces. ASTM specifies four general use categories: joists and planks, for pieces with thickness from 2 to 4 inches used in bending; beams and stringers, for pieces larger than 5 by 8 inches used in bending; posts and timbers, for pieces of square section, 5 by 5 inches and larger, used in compression; structural boards, for lumber less than 2 inches thick used primarily in axial tension or compression. These categories are general, and are not meant to preclude multiple uses of the various timber sizes. Note that these are nominal dimensions; due to the manufacturing procedures used to produced surfaced lumber, the actual dimensions may be as much as 1/2 inch smaller than nominal size.

Four factors are specified by ASTM D245 for use in determining the allowable design properties for a lumber grade or for a particular piece of lumber. These factors are the general adjustment factor, a, the strength ratio, SR, the seasoning adjustment, m, and an additional "special" factor B (ASTM does not assign symbols to these quantities). Using A to represent the allowable design properties for the timber, and C to represent the mechanical properties of the clear timber, the allow property equation is:

$$Allowable\ Property\ ,\ A,\ =\ C \times \left(\frac{1}{a}\right) \times SR \times m \times B \tag{5.31}$$

The mechanical property values for the clear wood, C, are the indicator properties developed through the use of the statistical analysis discussed in Section 5.4, and reported in Tables 5.5 and 5.6 and Appendix D. For all properties but modulus of elasticity and compression perpendicular to grain, C is the 5% exclusion limit. For modulus of elasticity and perpendicular compression, C is taken as the mean value.

The general adjustment factor, a, serves to adjust the allowable property for an assumed 10 year load duration, and includes a factor of safety of about 1.3 (17). The general adjustment factor varies with the property being developed; values for softwoods are listed in Table 5.7.

The seasoning adjustment, m, is used to correct the allowable properties for moisture contents other than that of green lumber when green lumber test results are used as the basis for developing the allowable design properties. Thus, either green test results may be corrected to provide design values for seasoned lumber, or tests of seasoned lumber may be used directly. ASTM provides two standard moisture content levels for design values. These values are $\leq 19\%$, and $\leq 15\%$, . Values of m are given in Table 5.8 for softwoods.

The special factor, B, is used to adjust bending stress ratios obtained using ASTM formulations for depth of member, as the ASTM formulations are based on a 2 inch member depth. This factor is only used when calculating the allowable bending strength. Using d to indicate the depth of a beam, B is calculated using an equation given by ASTM:

$$B = \left(\frac{2}{d}\right)^{\frac{1}{9}} \qquad (5.32)$$

TABLE 5.7: GENERAL ADJUSTMENT FACTOR, a, FOR SOFTWOODS

MECHANICAL PROPERTY	a
BENDING STRENGTH	2.1
MODULUS OF ELASTICITY, FLEXURE	.94
TENSILE STRENGTH, PARALLEL TO GRAIN	2.1
COMPRESSIVE STRENGTH, PARALLEL TO GRAIN	1.9
HORIZONTAL SHEAR STRENGTH	4.1
COMPRESSION PERPENDICULAR TO GRAIN	1.67

TABLE 5.8: SEASONING ADJUSTMENT FACTOR, m, FOR SOFTWOODS

MECHANICAL PROPERTY	PERCENTAGE INCREASE IN ALLOWABLE PROPERTY ABOVE THAT OF GREEN LUMBER, WHEN MAXIMUM MOISTURE CONTENT IS:	
	19%	15%
BENDING	25	35
MODULUS OF ELASTICITY	14	20
TENSION PARALLEL TO GRAIN	25	35
COMPRESSION PARALLEL TO GRAIN	50	75
HORIZONTAL SHEAR	8	13
COMPRESSION PERPENDICULAR TO GRAIN	50	50

The stress ratio, SR, is used to account for the presence of measurable defects in the graded lumber. ASTM provides definitions and measurement procedures for several types of defects, including knots, slope of grain, shakes, checks, and splits. The knot and slope of grain defects are assumed to affect bending, tension, and compression parallel to grain strengths, while shakes, checks, and splits are assumed to affect only the horizontal shear strength. The stress ratio that is used in equation 5.31 is to be the smallest value obtained once the stress ratios are developed for all defects present in the lumber grade.

The stress ratios associated with slope of grain are tabulated by ASTM and are reproduced here in Table 5.9. The stress ratios for slope of grain were obtained experimentally (4).

TABLE 5.9 STRESS RATIOS FOR SLOPE OF GRAIN

SLOPE OF GRAIN	STRESS RATIO, SR%	
	BENDING, OR TENSION PARALLEL TO GRAIN	COMPRESSION PARALLEL TO GRAIN
1 IN 6	40	56
1 IN 8	53	66
1 IN 10	61	74
1 IN 12	69	82
1 IN 14	74	87
1 IN 18	85	100
1 IN 20	100	100

The stress ratios which account for the presence of knots in timbers are derived using the moment or compression carrying capacity of a member with the cross section reduced by the presence of a knot typical of the largest knot allowed in the lumber grade (4). Combined compression and bending effects are not considered. Knots are considered to be either along the edge of the wide and/or narrow faces of the piece, or at the centerline of the wide face. Stress ratios are tabulated in ASTM D245, however, D245 also provides equations for calculating the ratios. The formulations use the actual member dimensions, with b and h representing the narrow width and wide width of the lumber, respectively, and k being the knot size measured as prescribed by ASTM D245. All values are in inches. Note that for a given defect type, several equations for SR may be given; the value of SR obtained from an equation is only valid if the conditions listed with the equations are met.

Bending stress ratios corresponding to knots in the narrow face of a member are given by the following equations:

$$SR \geq 45\ \%\ ; b \geq 6\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{\sqrt{6(b+(1/2))}}\right)$$

$$SR \geq 45\ \%\ ; b < 6\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{b+(3/8)}\right) \qquad (5.33)$$

$$SR < 45\ \% \qquad SR = 100\left(1 - \frac{k-(1/24)}{b}\right)$$

Bending stress ratios for knots at the edge of the wide face of a member, within the middle third of the length, are found using the following equations:

$$SR \geq 45\ \%\ ;6\ in. \leq h \leq 6\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{h+(1/2)}\right)^2$$

$$SR \geq 45\ \%\ ;h < 6\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{h+(3/8)}\right)^2$$

$$SR \geq 45\ \%\ ;h > 12\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{\sqrt{12(h+(1/2))}}\right)^2 \qquad (5.34)$$

$$SR < 45\ \%\ ;h \leq 12\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{h}\right)^2$$

$$SR < 45\ \%\ ;h > 12\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{\sqrt{12h}}\right)^2$$

Stress ratios for bending with knots along the center line of the wide face, and for compression parallel to grain, with knots at any point on any face are given using these equations:

$$SR \geq 45\ \% \ ;6\ in. \leq h \leq 12\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{h+(1/2)}\right)$$

$$SR \geq 45\ \% \ ;h < 6\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{h+(3/8)}\right)$$

$$SR \geq 45\ \% \ ;h > 12\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{\sqrt{12(h+(1/2))}}\right) \tag{5.35}$$

$$SR < 45\ \% \ ;h \leq 12\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{h}\right)$$

$$SR < 45\ \% \ ;h > 12\ in. \qquad SR = 100\left(1 - \frac{k-(1/24)}{\sqrt{12h}}\right)$$

Stress ratios for horizontal shear were developed by assuming that the critical cross section is reduced by the presence of the split, shake, or check. These defects are assumed to affect only the horizontal shear strength. Note that strength ratios below 50% are not used for shear, as a bending member that is split completely through its length will still support one-half of the shear load of an unsplit member (4). ASTM D245 provides charts and formulations for determining the shear stress ratios. The formulations use the actual member dimensions, with b and h representing the narrow width and wide width, respectively, and w being the defect size. All values are in inches.

Horizontal shear stress ratios for general use in members with shakes, checks, and splits may be found using the following equations:

$$b < 6\ in. \qquad SR = 100\left(1 - \frac{w-(1/24)}{b+(3/8)}\right) \tag{5.36}$$

$$b \geq 6\ in. \qquad SR = 100\left(1 - \frac{w-(1/24)}{b+(1/2)}\right)$$

Horizontal shear stress ratios for light construction members, with nominal thickness of 2 inches are developed based upon the length of the split and the width of the members wide faces:

$$SR = 100\left(1 - \frac{w}{3h}\right) \tag{5.37}$$

Stress ratios for tensile strength parallel to grain were developed from experimental results, and relate bending strength with tensile strength. The stress ratio is given by:

$$SR_{Tensile} = .55 \times SR_{Bending} \tag{5.38}$$

Member strengths in compression perpendicular to grain have been found to be relatively unaffected by the presence of defects. Therefore, strength ratios of 100% for compression perpendicular to grain are used for all lumber grades, with a standard deformation limit of .04 inches.

The stress ratios for modulus of elasticity serve as quality factors which relate the stiffness of a member to its bending strength ratio. The relationships were obtained experimentally, and are tabulated in Table 5.10.

TABLE 5.10: QUALITY FACTOR FOR MODULUS OF ELASTICITY

BENDING STRENGTH RATIO, %	SR FACTOR FOR MODULUS OF ELASTICITY, %
≥55	100
45 TO 54	90
≤44	80

The stress ratio factors given in Tables 5.7 through 5.10, and in equations 5.33 through 5.38 are to be used in equation 5.31 to obtain the allowable design values for the selected sizes and grades of lumber. The allowable properties are to be rounded to the nearest increment, using rules provided within ASTM D245, and summarized in Table 5.11.

TABLE 5.11: ASTM ROUNDING RULES

PROPERTY	ROUNDING INCREMENT
BENDING STRENGTH	NEAREST 50 PSI IF >1000 PSI NEAREST 25 PSI IF <1000 PSI
TENSION PARALLEL TO GRAIN	NEAREST 50 PSI IF >1000 PSI NEAREST 25 PSI IF <1000 PSI
COMPRESSION PARALLEL TO GRAIN	NEAREST 50 PSI IF >1000 PSI NEAREST 25 PSI IF <1000 PSI
HORIZONTAL SHEAR	NEAREST 5 PSI
COMPRESSION PERPENDICULAR TO GRAIN	NEAREST 5 PSI

5.5.2 NELMA and WWPA Requirements

ASTM D245, while providing procedures to correct for defects present within a grade of lumber, does not define the grades of lumber, nor the extent of the defects which are allowed in a particular grade. This task has been given to various grading rule agencies. These agencies produce guidelines and rules defining the grades of lumber, the defects the grades may contain, the intended uses of the grades, and the procedures to be followed in visually grading lumber. Grading organizations fall under the jurisdiction of the American Lumber Standards Committee, and other government organizations (25).

The two sets of grading rules used to develop the allowable design properties for Alaskan White Spruce are those published by the Western Wood Products Association (WWPA), and the Northeastern Lumber Manufactures Association (NELMA). Both of these grading rules are nationally recognized. The two sets of rules were used together, in order to ensure that any allowable design properties developed herein could be more readily compared with existing design properties for dimension lumber. The two sets of grading rules are nearly identical, with the exception that WWPA includes rules for somewhat larger members than does NELMA. The more stringent rule was always applied in this study to ensure compatibility with both rule sets.

The grading rules are simply a list of defects, and the extent to which these defects may exist in a piece of timber that is sorted into a particular grade. Thus, the grading rule defines the lowest quality member which will be encountered in a given grade. Allowable design properties are then assigned to the group based on this worst case member using the procedures of ASTM D245.

NELMA and WWPA specify several dozen grades of lumber, for end uses varying from pencil manufacturing to mine shoring. Allowable design properties for Alaskan White Spruce were developed for six categories of lumber; each category contains several grade levels. Allowable design values for a total of fourteen structural grades were developed. The categories, grades, and sizes contained in each category are shown in Table 5.12.

TABLE 5.12: NELMA/WWPA CLASSIFICATIONS AND GRADES

STRUCTURAL LIGHT FRAMING		STUDS	
NO.1	2"-4" THICK 2"-4" WIDE	STUD	2"-4" THICK 2"-6" WIDE
NO.2			
NO.3			
STRUCTURAL JOISTS & PLANKS		**BEAMS & STRINGERS**	
NO.1	2"-4" THICK 5" AND WIDER	NO.1	5" AND WIDER DEPTH ≥ WIDTH + 2"
NO.2		NO.2	
NO.3			
LIGHT FRAMING		**POSTS & TIMBERS**	
CONSTRUCTION	2"-4" THICK 4" WIDE	NO.1	5" AND WIDER DEPTH ≤ WIDTH + 2"
STANDARD		NO.2	
UTILITY			

The two Structural categories, the Stud category, and the Light Framing category are all intended for use in typical wood frame construction, and consist mostly of small to moderately sized sections. The Beam and Stringer category, and the Post and Timber category are intended for heavy timber construction, with beams being used primarily in flexure, and posts being used primarily in compression. The grades within each timber category indicate a "quality" level associated with each grade. The grades reflect the type and extent of defects contained in a grade, and thus affect the allowable design values for that grade. The quality levels for one category are not directly relatable to the qualities of other categories; a No.2 Beam is of much lower quality than a No.2 Structural Joist, and has lower design values than the joist.

An example of a grade definition, as given by NELMA and WWPA for a No.1 Structural Joist & Plank is presented in Table 5.13. The requirements given by the grading rule are extensive and comprehensive. Several of the requirements place limits on quality or manufacturing tolerances; these requirements have little bearing on the allowable design properties. The requirements which effect the allowable properties most are: knots, checks, shake, splits, and slope of grain. Appendix E contains charts showing the NELMA/WWPA grading rule requirements for knots, shake, splits, and slope of grain, along with the stress ratios derived using the rules for each of the lumber grades evaluated during this project.

TABLE 5.13: TYPICAL NELMA/WWPA GRADING RULE

RULE 20.2 NO.1 STRUCTURAL JOISTS AND PLANKS

Dimension lumber of this quality is limited in characteristics that effect strength and stiffness values to provide a fiber stress bending value of 55% of that allowed for clear, straight-grained wood and to provide a recommended design value for modulus of 100% of that allowed for the clear wood average. This grade is recommended for construction where high strength and stiffness and good appearance are desired.

Characteristics permitted and limiting provisions shall be:

Checks -- Surface seasoning checks, not limited. Through checks at end limited as splits.
Knots -- Sound, firm, encased, and pith knots, if tight and well spaced, are permitted in sizes not to exceed the following or equivalent displacement:

Nom. Width	At Edge Wide Face	Centerline Wide Face	Unsound & Holes
5"	1 1/4"	1 7/8"	1 1/8"
6"	1 1/2"	2 1/4"	1 1/4"
8"	2"	2 3/4"	1 1/2"
10"	2 1/2"	3 1/4"	1 1/2"
12"	3"	3 3/4"	1 1/2"
14"	3 1/8"	4"	1 1/2"
16"	3 1/4"	4 1/2"	1 1/2"
18"	3 3/8"	4 5/8"	1 1/2"

Manufacture -- Standard "E". See para. 722.
Pitch and Pitch Streaks -- Not limited.
Pockets: Pitch or Bark -- Not limited.
Shake -- On ends limited to 1/2 thickness. Away from ends several heart shakes up to 2' long, none through.
Skips -- Hit and miss skips in 10% of pieces. See para 720.
Slope of Grain -- 1 in 10.
Splits -- Equal in length to width of the piece.
Stain -- Stained sapwood. Firm heart stain or firm red heart.
Wane -- 1/4 the thickness, 1/4 the width, 5% of pieces may have wane up to 1/2 the thickness and 1/3 the width for 1/4 the length.
Warp -- 1/2 of medium. See para 752.

5.5.3 Allowable Property Determination

The allowable design properties for Alaskan White Spruce were determined using the NELMA and WWPA grading rules described in Section 5.5.2, and the procedures of ASTM Document D245.

Clear wood mechanical strength values were selected from the results of the statistical analysis described in Section 5.3, as presented in Tables 5.5, 5.6 and Appendix D. As several probability density functions were used in the analysis, selection of the clear wood strength values was made using the results of the χ^2 goodness-of-fit test, and with reference to the histogram plots contained in Appendix C.

Note that the values in Tables 5.5, 5.6 and Appendix D are for wood at a moisture content of 12%; these values are adjusted to a moisture level of 19% to match the ASTM D245 standard for normal seasoned lumber. Moisture content adjustment was made using the procedures described in Section 5.2.3, in particular equation 5.11.

The selected clear wood strength values are shown in Table 5.14. All values shown are 5% exclusion limits, except in the case of modulus of elasticity, and compression perpendicular to grain where the mean values are given. Note that only the properties most frequently used in structural design are shown in this table; other test results such as cleavage or hardness do not receive the ASTM D245 defect adjustments.

TABLE 5.14: CLEAR WOOD STRENGTH VALUES FOR ALASKAN WHITE SPRUCE

PROPERTY (PSI)	12% M.C.	19% M.C.
BENDING STRENGTH	7857	6525
TENSILE STRENGTH	7857	6525
SHEAR STRENGTH	591	538
PERPENDICULAR COMPRESSION	725	537
PARALLEL COMPRESSION	5460	3999
MODULUS OF ELASTICITY	1,513,000	1,347,000

Tables showing the pertinent defects allowed in each grade were created using the NELMA/WWPA grading rules. These charts show the various sizes and locations of knots allowed in each grade, the allowable degree of shake and splits, and the allowable slope of grain. These tables are given in Appendix E. An example of one of these tables is shown in Table 5.15.

Using the tables and formulas provided by ASTM in Document D245, the appropriate stress ratios for each of the tabulated defects was calculated using Tables 5.8 through 5.11 and equations 5.33 through 5.38. Also, the general adjustment factors were obtained using Table 5.7, and the special factor, B, was calculated using equation 5.32.

Using equation 5.31, all of the stress ratios and adjustment factors were combined to produce a composite adjustment factor for each of the mechanical properties contained within each grade. Thus, a composite factor was

TABLE 5.15: ALLOWABLE PROPERTY DEVELOPMENT TABLE

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT NO.1 STRUCTURAL JOISTS AND PLANKS					
KNOT TYPE DEFECTS					
NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		BENDING		COMPRESS
NOMINAL WIDTH	EDGE WIDE FACE	CENTERLINE WIDE FACE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
5	1.25	1.875	.57	.62	.62
6	1.5	2.25	.57	.62	.62
8	2	2.75	.57	.66	.66
10	2.5	3.25	.57	.69	.69
12	3	3.75	.57	.69	.69
14	3.125	4	.58	.69	.69
16	3.25	4.5	.60	.68	.68
18	3.375	4.625	.60	.68	.68

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS					
ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.55			
MODULUS QUALITY	= 100%				
STRESS RATIO FROM ABOVE					
SHAKE	1/2 THICKNESS				.55
SLOPE OF GRAIN	1 IN 10	.61	.61	.74	
SPLITS	= THICKNESS				.67
SPECIAL BENDING FACTOR	(2/18)^(1/9)	.7834			

DESIGN PROPERTY CALCULATIONS							
PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.55	.7834	.2052	6525	1338	1350
TENSILE	2.1	.55 X .55		.1440	6225	939	950
SHEAR	4.1	.55		.134	538	72	70
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.62		.3263	3999	1304	1300
MODULUS	.94	1.0		1.064	1.347	1.433	1.40

created for each of the following: bending, compression parallel to grain, tension parallel to grain, compression perpendicular to grain, horizontal shear, and for modulus of elasticity. These composite factors are presented in the defect charts shown in Table 5.15 and in Appendix E.

The allowable design properties for Alaskan White Spruce are then calculated by multiplying the clear wood strength values listed in Table 5.14 by the composite adjustment factors developed in the defect charts, as shown in Table 5.15. The allowable values are shown in the defect charts in both a raw, and rounded form. Rounding of design values was conducted according to ASTM D245, as shown in Table 5.11.

A summary of the allowable design properties resulting from this analysis is shown in Table 5.16. This table is the desired end-result of the entire wood testing procedure. The table is based on the format used in the 1986 edition of the National Design Specification for Wood Construction.

TABLE 5.16: ALASKAN WHITE SPRUCE ALLOWABLE DESIGN VALUES

GRADE	SIZE	DESIGN VALUES IN POUNDS PER SQUARE INCH					
		BENDING "F_b"	TENSION PARALLEL TO GRAIN "F_T"	HORIZONTAL SHEAR "F_V"	COMPRESSION PERPENDICULAR TO GRAIN "$F_{C\perp}$"	COMPRESSION PARALLEL TO GRAIN "F_C"	MODULUS OF ELASTICITY "E"
STRUCTURAL FRAMING							
NO.1	2" TO 4" THICK	1550	950	70	320	1200	1,400,000
NO.2		1300	775	65	320	1050	1,300,000
NO.3	2" TO 4" WIDE	700	450	65	320	625	1,100,000
STUD		750	450	65	320	625	1,100,000
LIGHT FRAMING							
CONSTRUCT	2" TO 4" THICK	975	575	65	320	1100	1,100,000
STANDARD		550	325	65	320	850	1,100,000
UTILITY	4" WIDE	250	150	65	320	625	1,100,000
JOISTS AND PLANKS							
NO.1	2" TO 4" THICK 5" AND WIDER	1350	950	70	320	1300	1,400,000
NO.2		1100	775	65	320	1100	1,300,000
NO.3		625	450	65	320	675	1,100,000
STUD	6" WIDE	700	450	65	320	675	1,100,000
BEAMS AND STRINGERS							
NO.1	5" AND WIDER DEPTH ≥ WIDTH+2"	1200	600	65	320	725	1,100,000
NO.2		775	325	65	320	400	1,100,000
POSTS AND TIMBERS							
NO.1	5" AND WIDER DEPTH ≥ WIDTH+2"	1100	825	65	320	850	1,100,000
NO.2		625	450	65	320	300	1,100,000

CHAPTER 6: DISCUSSION OF RESULTS

6.1 Discussion of Results

It is almost always useful to compare the results of a testing procedure with the results of earlier research. The comparisons given herein serve several purposes.

The first set of comparisons made here is between the Alaskan White Spruce mechanical properties test results obtained during this study, and the results of previously performed mechanical properties testing of White Spruce. The comparisons are presented in Sections 6.2 and 6.3 and are intended to highlight the differences in mechanical properties between several samples of White Spruce grown in different locations. The comparisons also show the values obtained during this testing sequence to be within expected tolerances.

The second set of comparisons is given in Section 6.4, and consists of the allowable design values developed for Alaskan White Spruce versus the allowable values for other species of lumber which are brought into Alaska for construction projects. The comparison is made using two species of trees harvested in the continental United States, including Douglas Fir/Larch and Spruce/Pine/Fir. The purpose of these comparisons is to demonstrate the worth of Alaskan White Spruce relative to other species of lumber brought into Alaska.

6.2 Comparison of Mechanical Property Values

Comparisons of the mechanical properties for Alaskan White Spruce from the Birch Lake sample site developed during the course of this research project and other published data for White Spruce are useful both in the determination of general trends and in the validation of the new data. Five sets of previously collected data from three sources are used for the comparison.

Previously existing data for White Spruce mechanical properties is contained in two U.S. Forest Research Papers, and in the Wood Engineering Handbook. Each of these sources is discussed in detail in the literature review, Sections 2.1.1 and 2.1.2, and are only briefly reviewed here.

U.S. Forest Research Paper FPL1, titled "Characteristics of Alaska Woods" published in 1963 contains the results of mechanical property tests on various species of trees tested from both Alaska, and the Continental United States. One of the tested species was White Spruce; FPL1 contains data for two sites in the contiguous United States and one site in Alaska (15). U.S.D.A. Forest Service Research Paper FPL237, titled "Specific Gravity and Mechanical Properties of Black, Red, and White Spruces, and Balsam Fir", published in 1974 contains the results of mechanical property re-evaluations conducted on woods from the continental United States (16). The Wood Engineering Handbook contains mechanical property values for White Spruce grown in Canada, and imported into the United States (17).

The data from these three sources has been complied into Table 6.1. This table has columns containing the mechanical property data, with rows for each of the tested sample sites presented in the literature. Mechanical properties are given for green wood, and for seasoned wood adjusted to a 12% moisture content. All values in the table are mean values. The last set of data in the table that collected for Alaskan White Spruce during the course of this research project. This data was selected from the values presented in Tables 5.5 and 5.6 using the χ^2 test described in Section 5.3.4.

TABLE 6.1: COMPARISON OF WHITE SPRUCE MECHANICAL PROPERTIES

WHITE SPRUCE TEST SITE OR STUDY	SPECIFIC GRAVITY	SHRINKAGE VOL.	SHRINKAGE RAD.	SHRINKAGE TAN.	STATIC BENDING MODULUS OF: RUPTURE	STATIC BENDING MODULUS OF: ELASTIC.	COMP. STRENGTH PARALLEL TO GRAIN	COMP. STRENGTH PERPEND. TO GRAIN	SHEAR STRENGTH PARALLEL TO GRAIN	TENSILE STRENGTH PERPEND. TO GRAIN	HARDNESS LOAD END	HARDNESS LOAD SIDE
UNITS		(%)	(%)	(%)	(PSI)	(KSI)	(PSI)	(PSI)	(PSI)	TO GRAIN	(LBS)	(LBS)
FPL1: CONTIGUOUS U.S.., 1963												
COOS COUNTY, N.H.												
GREEN	0.35	---	---	---	5700	1060	2440	280	680	---	220	240
SEASONED	0.37	---	---	---	9300	1360	5020	460	1130	350	540	440
RUSK COUNTY, WIS.												
GREEN	0.38	14.8	3.7	7.3	5400	990	2550	270	690	200	290	280
SEASONED	0.41	---	---	---	9000	1500	5320	540	770	---	700	530
FPL237: CONTIGUOUS U.S., 1974												
EIGHT STATES												
GREEN	0.33	---	---	---	4995	1141	2349	210	636	---	318	274
SEASONED	0.36	---	---	---	9448	1429	5178	432	972	---	519	409
IMPORTED CANADIAN TIMBER:												
GREEN	0.35	---	---	---	5100	1150	2470	240	670	---	---	---
SEASONED	---	---	---	---	9100	1450	5360	500	980	---	---	---
FPL1: ALASKA STATE , 1963												
MATANUSKA VALLEY												
GREEN	0.39	12.6	5.8	9.1	5700	1150	2720	330	710	230	370	350
SEASONED	0.43	---	---	---	10600	1400	6230	740	1310	390	640	500
THIS STUDY, ALASKA STATE,1993												
BIRCH LAKE												
GREEN	.37	11.9	4.7	7.6	5282	1180	2802	241	484	299	357	321
SEASONED	.42	---	---	---	9507	1514	6324	463	776	396	550	467

The data sets are also presented in Table 6.2. In this table, the data has been normalized by dividing the data sets by the values for Alaskan White Spruce. Presented in this format, the data represents the values for all data sets as a percentage of the Alaskan White Spruce data obtained during this study; such a presentation makes differences (or similarities) between the data sets more readily apparent.

The first item to compare is specific gravity. Referring to Table 6.1, the specific gravity for White Spruce grown in Alaska is higher in some cases than the specific gravity for white spruce from outside of Alaska. This reflects the colder growing conditions of the Alaskan climate which results in slower growing trees. Canada, having a climate similar to Alaska differs less from Alaska in specific gravity than does most of the United States. Comparing the two sample sites of Alaskan White Spruce against each other, it can be seen the Birch Lake Sample site has about the same specific gravity as the Matanuska Valley Sample site.

Comparison of shrinkage data is inconclusive. Matanuska Valley spruce has volumetric shrinkage similar to that of Birch Lake spruce, while its radial and tangential shrinkages are about 20 percent higher. The opposite trends are shown by comparison with the Rusk County white spruce; here volumetric shrinkage is about 20 percent higher than for the Birch Lake Spruce, while the radial and tangential values are 20 some percent less. The shrinkage values obtained for the Birch Lake sample site seem reasonable, but as this is an obviously variable property no solid conclusions can be made with the available data.

Two items are compared for the static bending test: modulus of rupture, and modulus of elasticity. Comparing the values for seasoned wood, the data show the modulus of rupture for Alaskan White Spruce to be slightly (approximately 5%) higher than most of the non-Alaska test data. Referring to

TABLE 6.2: NORMALIZED WHITE SPRUCE MECHANICAL PROPERTIES

WHITE SPRUCE TEST SITE OR STUDY	SPECIFIC GRAVITY	SHRINKAGE			STATIC BENDING MODULUS OF:		COMP. STRENGTH PARALLEL TO GRAIN	COMP. STRENGTH PERPEND. TO GRAIN	SHEAR STRENGTH PARALLEL TO GRAIN	TENSILE STRENGTH PERPEND. TO GRAIN	HARDNESS LOAD	
		VOL.	RAD.	TAN.	RUPTURE	ELASTIC.					END	SIDE
UNITS		(%)	(%)	(%)	(PSI)	(KSI)	(PSI)	(PSI)	(PSI)	(PSI)	(LBS)	(LBS)
FPL1: CONTIGUOUS U.S., 1963												
COOS COUNTY, N.H.												
GREEN	0.95	---	---	---	1.08	.90	.87	1.16	1.40	---	.61	.75
SEASONED	0.88	---	---	---	.98	.90	.79	.99	1.46	.88	.98	.94
RUSK COUNTY, WIS.												
GREEN	1.02	1.24	.79	.97	1.02	.84	.91	1.12	1.43	.67	.81	.87
SEASONED	0.98	---	---	---	.95	.99	.84	1.17	.99	---	1.27	1.13
FPL237: CONTIGUOUS U.S., 1974												
EIGHT STATES												
GREEN	.89				.95	.97	.84	.87	1.31	---	.89	.85
SEASONED	0.86	---	---	---	.99	.94	.82	.93	1.25	---	.94	.88
IMPORTED CANADIAN TIMBER:												
GREEN	0.95	---	---	---	.97	.97	.88	1.00	1.38			
SEASONED	---	---	---	---	.96	.96	.85	1.08	1.26	---	---	---
FPL1: ALASKA STATE, 1963												
MATANUSKA VALLEY												
GREEN	1.05	1.05	1.23	1.20	1.08	.97	.97	1.36	1.47	.77	1.03	1.09
SEASONED	1.02	---	---	---	1.11	.92	.98	1.60	1.69	.98	1.16	1.07
THIS STUDY, ALASKA STATE, 1993												
BIRCH LAKE												
GREEN	1	1	1	1	1	1	1	1	1	1	1	1
SEASONED	1	---	---	---	1	1	1	1	1	1	1	1

Appendix D, it can be seen that from the confidence intervals that the lowest expected value for the Alaskan White Spruce modulus of rupture in seasoned wood is 9318 psi. This lower limit is higher than all of the non-Alaskan data except for the FPL237 data; this indicates the slightly higher strength value obtained here may be due to actual material differences rather than statistical uncertainty. In examining the green wood modulus of rupture values, the modulus of rupture is slightly (2 and 8 percent) lower for Alaskan White Spruce in two cases, and slightly higher in two cases (3 to 5 percent) than for Spruce sampled outside of Alaska; there seems to be no real difference in the green wood bending strength. Comparing the Matanuska Valley data against the Birch Lake data, it can be seen that the Matanuska Valley samples are about 10 percent stronger than the Birch Lake samples.

The modulus of elasticity for Alaskan White Spruce is higher than that of spruce grown elsewhere, as much as 15% in the case of the green wood values from the Rusk County sample site. In comparing the Matanuska Valley sample site against the Birch Lake sample site the Birch Lake samples are similar in stiffness to the other Alaskan samples.

Examining the strength data for compression parallel to grain, it is apparent Alaska White Spruce is stronger in compression than White Spruce grown elsewhere. The samples from Birch Lake are as much as 15% stronger than the reported contiguous U.S. and Canadian White Spruce samples, while the values from the two Alaskan sample sites agree with each other within about 3 percent. From the confidence intervals given in Appendix D, the smallest values expected for the compressive strength means are 6242 psi and 2741 psi for the seasoned and green wood respectively. These values are greater than the means from the non-Alaskan data, indicating the strength differences are due to material differences in the samples.

The results of comparing the compressive strengths perpendicular to grain of the six data sets is not clear. Referring to Table 6.2, it can be seen that one of the data sets from outside Alaska is weaker than the Birch Lake data, one is roughly equal to it, and the other two are greater than it. However, the Matanuska Valley data values are much higher than any of the other data, being as much as 30% greater than the Continental U.S. values, and 60% greater than the Birch Lake values. Like shrinkage, the perpendicular compression strength seems to be a widely variable property, and no conclusions can be drawn from the available data.

Comparison of shear strength values from the Birch Lake sample site with values from the other five data sets indicates the spruce tested here possesses low shear strength, about 25 and 45% to lower strength than spruce from the contiguous U.S. However, shear strength values for the Matanuska Valley site show Alaskan White Spruce to be 30 to 70 percent stronger in shear than White Spruce grown outside of Alaska. Also, the Rusk County Sample site agrees closely with the shear strength of the Birch Lake Site, at least for seasoned wood. Not enough data is available to make conclusions about the shear strength of Alaskan White Spruce.

The perpendicular tension samples from the Birch Lake sample site tested between 12 and 35 percent stronger than the two contiguous U.S. sample sites available for comparison. However, as only one data set is available for comparison in each of the green and seasoned conditions, it is not possible to conclude that Alaskan White Spruce is stronger in perpendicular tension. Green wood from the Birch Lake sample site tested about 25 percent stronger than the Matanuska site, while the seasoned values for perpendicular tension were roughly the same.

Hardness values for the Birch lake sample site were slightly (2 to 10%) higher than values for White Spruce from outside Alaska, in the case of seasoned wood, except in the case of the Rusk County samples, which were about 15 to 30 percent higher than the Birch Lake samples. Green wood samples from Birch Lake were as much as 50% higher in hardness than the non-Alaskan samples. Within Alaska, the Matanuska Valley sample site has slightly higher values than the Birch Lake site, being 3 to 10% harder in the green wood, and 7 to 17 percent harder in the seasoned wood. The hardness values for the Birch Lake sample site seem reasonable.

With the possible exception of the shear parallel to grain strength values, the test results from the Birch Lake sample site seem reasonable when compared with the sample sites from Canada, the Continental United States, and Alaska. While the Birch Lake test results are frequently higher than results from the sample sites outside Alaska, the values are in general similar to test results from the Matanuska Valley.

It is reasonable, however, that the values for the Birch Lake sample site, and for Alaska in general are somewhat higher than strength values from outside Alaska due to the fact the Alaskan White Spruce has a higher specific gravity. The mechanical properties of a wood species have been shown to increase with the specific gravity of the samples (18,20).

6.3 Comparison of Sample Set Variations

U.S.D.A Forest Service Research Paper FPL 237, as mentioned in Section 6.2.1, contains the results of testing performed on several species of spruce and balsam fir from the United States (16). This reference is more comprehensive than the remainder of the references mentioned in Section 6.2, in that FPL237 includes values for the standard deviation, the coefficient of variation, and the 95 percent confidence interval about the mean, in addition to the mean values for the test results. The other references merely give the mean value for the test results, with no indication of the data set's consistency.

The statistical data included in FPL 237 allows a detailed comparison between previously tested White Spruce and the test results from the Birch Lake sample site, particularly with regard to the coefficients of variation. The intent of this comparison is to demonstrate the consistency of the testing procedures used during this project, and to demonstrate the consistency of the sampled wood.

Mean values, standard deviations, coefficients of variation, and 95 percent confidence intervals about the mean for Alaskan White Spruce and for White Spruce from the contiguous U.S. (as reported in FPL237) are summarized in Table 6.3. The values given for Alaskan White Spruce were selected from Tables 5.5 and 5.6 and Appendix D based on the χ^2 test as described in Section 5.3.4.

Two things may be seen upon inspection of the data in Table 6.3: First, in most cases, more tests were conducted upon the Alaskan White Spruce samples from Birch Lake than upon the sample sites listed in the FPL 237 program. Second, the Alaskan White Spruce test results have lower standard deviations than the test results given in FPL237.

The number of tests preformed upon the Birch Lake sample site was governed by ASTM D143. Thirty trees from a single sample site were tested, with many tests being perform-ed on each tree. Forest Products Laboratory, in their efforts to obtain a representative forest sample for the FPL237 project did not use the ASTM D143 testing schedule; rather, Forest Products Laboratory collected 34 White Spruce trees

TABLE 6.3: COMPARISON OF DATA SET VARIATIONS

PROPERTY	NUMBER OF OBSERVATIONS	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION (%)	95 % CONFID. INTERVAL ABOUT THE MEAN
SPECIFIC GRAVITY					
AK GREEN	20	.369	.024	6.5	±.011
US GREEN	34	.328	.034	10.2	±.012
AK SEASONED	20	.418	.031	7.4	±.014
US SEASONED	34	.361	.044	12.3	±.014
BENDING: MODULUS OF RUPTURE (PSI)					
AK GREEN	164	5281	492	9.3	±76
US GREEN	34	4995	878	17.6	±306
AK SEASONED	110	9507	989	10.4	±187
US SEASONED	34	9448	1729	18.3	±603
BENDING: MODULUS OF ELASTICITY (KSI)					
AK GREEN	164	1180	136	11.5	±21
US GREEN	34	1141	265	23.2	±93
AK SEASONED	110	1514	218	14.4	±41
US SEASONED	34	1429	337	23.6	±118
PARALLEL COMPRESSION: STRENGTH (PSI)					
AK GREEN	74	2802	266	9.5	±62
US GREEN	34	2349	439	18.7	±153
AK SEASONED	154	6324	519	8.2	±83
US SEASONED	34	5178	860	16.6	±300
PARALLEL COMPRESSION: MODULUS OF ELASTICITY(KSI)					
AK GREEN	74	1287	320	24.9	±74
US GREEN	34	1370	377	27.5	±132
AK SEASONED	153	1767	243	13.3	±84
US SEASONED	34	1647	393	23.9	±137

TABLE 6.3, CONTINUED: COMPARISON OF DATA SET VARIATIONS

PROPERTY	NUMBER OF OBSERVATIONS	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION (%)	95 % CONFID. INTERVAL ABOUT THE MEAN
SHEAR STRENGTH RAD AND TAN AVERAGE (PSI)					
AK GREEN	34	484	69	14.2	±24
US GREEN	68	636	60	10.3	±12
AK SEASONED	111	776	112	14.5	±21
US SEASONED	68	972	144	14.8	±29
PERPENDICULAR COMP. AT PROPORTIONAL LIMIT (PSI)					
AK GREEN	68	241	42.3	17.5	±10
US GREEN	34	210	51.3	24.5	±18
AK SEASONED	61	463	65.5	14.2	±17
US SEASONED	34	432	107	24.7	±37
HARDNESS:END (LBS)					
AK GREEN	60	357	38.3	10.7	±10
US GREEN	34	318	41.0	12.9	±15
AK SEASONED	53	550	47.2	8.6	±13
US SEASONED	34	519	92.3	17.8	±32
HARDNESS: SIDE (LBS)					
AK GREEN	60	321	49.0	15.3	±13
US GREEN	34	274	40.9	12.9	±15
AK SEASONED	53	467	50.5	10.8	±14
US SEASONED	34	409	83.6	20.4	±29

from around the contiguous U.S., and tested one or two samples from each tree. As a result of the varied nature of the FPL237 sample and the relatively low number of samples used, the FPL test data has some degree of variability, as indicated by the standard deviations shown in Table 6.3.

The FPL237 data has larger standard deviations than does the Birch Lake data; thus, the resulting coefficients of variation are lower for the Birch Lake data, as are the confidence intervals about the mean. The narrow confidence intervals for the Birch Lake data are partially due to the consistency of the data, although the relatively large number of samples tested also results in a smaller interval. This is because the interval calculation uses the sample size as a divisor (see Section 5.3.5). The low coefficients of variation, and the small confidence intervals indicate the Birch Lake test results have a high degree of consistency. In two instances the Birch Lake data does have a coefficient of variation higher than the FPL237 data, namely in the cases of green shear strength and green hardness in side grain.

The Birch Lake data may be compared against the variability of wood in general, as the Forest Products Laboratory has averaged the coefficients of variation from approximately 50 test series on various species of timber; these average values for the coefficient of variation are reproduced in Table 6.4 (17), along with the coefficients of variation for the seasoned wood from Birch Lake.

The coefficients of variation for the Alaskan White Spruce tested from the Birch Lake sample site are lower than the average coefficients listed in Table 6.4. In general the test data collected during this project is at least as consistent as the average mechanical property test preformed on wood, and probably more so. The low coefficients of variation are likely due to two items. First, it is possible the samples collected from Birch lake were of an inherently consistent nature. Second, the automated testing procedures and equipment developed during this project, as described in Chapter 4 exhibit high degrees of accuracy and repeatability, thus eliminating many sources of error and variability present in other timber testing techniques.

TABLE 6.4: COEFFICIENTS OF VARIATION FOR WOOD (17)

PROPERTY	C.O.V % FPL DATA	C.O.V. %, THIS PROJECT
SPECIFIC GRAVITY	10	7.4
BENDING MODULUS OF RUPTURE	16	10.4
BENDING MODULUS OF ELASTICITY	22	14.4
PARALLEL COMPRESSION	18	8.2
SHEAR STRENGTH	14	14.5
PERPENDICULAR COMPRESSION	28	14.2
HARDNESS	20	10.8

6.4 Comparison of Allowable Design Properties

In order to understand the considerable value of Alaskan White Spruce as a construction material, comparisons between the allowable design properties of Alaskan White Spruce, and other common species of construction lumber are useful. Two types of lumber commonly brought into Alaska for construction purposes are Douglas-Fir/Larch from the Pacific-Northwestern part of the United States, and Spruce/Pine/Fir from various parts of Canada. Both of these lumber types consist of two or more mixed species of trees which are harvested, milled, and graded without consideration to the species. This is convenient, however, the properties assigned to a group of mixed species must account for the variation in strength between the species in the mixed designation, and the proportions of the species present, relative to each other. This generally devalues the stronger species in the combinations.

As an example, Western Larch is somewhat stronger than Douglas-Fir, but the species combination of Douglas-Fir/Larch has allowable properties much closer to Douglas Fir than those of the Larch. This is because the Douglas-Fir is less strong than the Larch, and because most of the lumber in the species combination is Douglas Fir. The Alaskan White Spruce species is not likely to be mixed with other species of softwoods during normal logging operations, and will thus retain the high strength values of a single species designation.

Allowable design data for Douglas-Fir/Larch, and for Spruce/Pine/Fir lumber is available in the National Design Specifications for Wood Construction (NDS), produced by the National Forest Products Association (26,27). Two editions of the NDS are referenced herein, the 1986 edition, and the 1991 edition, which is meant to supersede all earlier editions. The two editions both contain allowable design data, but the source and presentation of the data in the two editions is different, due to major changes between the 1986 and 1991 editions.

The 1986 NDS contains allowable properties which were developed by applying correction factors to mechanical test results obtained using small, clear specimens, in the same manner as the testing reported herein for Alaskan White Spruce. This was done using the methodologies of ASTM documents D245 and D143. The allowable properties in the 1986 NDS are supplied in the same format as Table 5.15, with allowable properties given for each lumber size group. The allowable property values in the 1986 NDS may be directly compared with the Alaskan White Spruce values in this report.

The 1991 NDS contains allowable properties which were developed using full-size, in-grade testing, using the methodologies of ASTM Documents D1990 and D198. The allowable properties are presented in a format which lists the design values for each grade of timber, but not for each size group. A size factor given within the 1991 NDS must be used to modify the tabulated values for the different size groups before comparisons may be made.

Tables 6.5 and 6.6 were developed using allowable design data from the NDS, respectively, and the Alaskan White Spruce properties developed during this project. Table 6.5 is based on the 1986 edition, while Table 6.6 is based on the 1991 edition, corrected for member size. Alaska White Spruce values are shown in **bold type**, Douglas-Fir/Larch values are in *italic type*, and Spruce/Pine/Fir values are in normal type.

TABLE 6.5: DESIGN VALUE COMPARISON (1986 NDS VALUES)

GRADE	SIZE	DESIGN VALUES IN POUNDS PER SQUARE INCH BENDING "F_b"	TENSION PARALLEL TO GRAIN "F_t"	HORIZONTAL SHEAR "F_v"	COMPRESSION PERPENDICULAR TO GRAIN "$F_{c\perp}$"	COMPRESSION PARALLEL TO GRAIN "F_c"	MODULUS OF ELASTICITY "E"
STRUCTURAL FRAMING							
NO.1	2" TO 4" THICK	**1550**	**950**	**70**	**320**	**1200**	**1,400,000**
		1750	*1050*	*95*	*625*	*1250*	*1,800,000*
		1200	725	70	425	875	1,500,000
NO.2	2" TO 4" WIDE	**1300**	**775**	**65**	**320**	**1050**	**1,300,000**
		1450	*850*	*95*	*625*	*1000*	*1,700,000*
		1000	600	70	425	675	1,300,000
NO.3		**700**	**450**	**65**	**320**	**625**	**1,100,000**
		800	*475*	*95*	*625*	*600*	*1,500,000*
		550	325	70	425	425	1,200,000
STUD		**750**	**450**	**65**	**320**	**625**	**1,100,000**
		800	*475*	*95*	*625*	*600*	*1,500,000*
		550	325	70	425	425	1,200,000
LIGHT FRAMING							
CONSTRUCT	2" TO 4" THICK	**975**	**575**	**65**	**320**	**1100**	**1,100,000**
		1050	*625*	*95*	*625*	*1150*	*1,500,000*
		725	425	70	425	775	1,200,000
STANDARD	4" WIDE	**550**	**325**	**65**	**320**	**850**	**1,100,000**
		600	*350*	*95*	*625*	*925*	*1,500,000*
		400	225	70	425	650	1,200,000
UTILITY		**250**	**150**	**65**	**320**	**625**	**1,100,000**
		275	*175*	*95*	*625*	*600*	*1,500,000*
		175	100	70	425	425	1,200,000
JOISTS AND PLANKS							
NO.1	2" TO 4" THICK	**1350**	**950**	**70**	**320**	**1300**	**1,400,000**
		1500	*1000*	*95*	*625*	*1250*	*1,800,000*
		1050	700	70	425	875	1,500,000
NO.2	5" AND WIDER	**1100**	**775**	**65**	**320**	**1100**	**1,300,000**
		1250	*650*	*95*	*625*	*1050*	*1,700,000*
		875	450	70	425	725	1,300,000
NO.3		**625**	**450**	**65**	**320**	**675**	**1,100,000**
		725	*375*	*95*	*625*	*675*	*1,500,000*
		500	275	70	425	450	1,200,000
STUD	6" WIDE	**700**	**450**	**65**	**320**	**675**	**1,100,000**
		725	*375*	*95*	*625*	*675*	*1,500,000*
		500	275	70	425	450	1,200,000
BEAMS AND STRINGERS							
NO.1	5" AND WIDER	**1200**	**600**	**65**	**320**	**725**	**1,100,000**
		1300	*675*	*85*	*625*	*925*	*1,600,000*
		900	450	65	425	625	1,300,000
NO.2	DEPTH ≥ WIDTH+2"	**775**	**325**	**65**	**320**	**400**	**1,100,000**
		875	*425*	*85*	*625*	*600*	*1,300,000*
		600	300	65	425	425	1,000,000

TABLE 6.6: DESIGN VALUE COMPARISON (1991 NDS VALUES)

GRADE	SIZE	DESIGN VALUES IN POUNDS PER SQUARE INCH					
		BENDING "F_b"	TENSION PARALLEL TO GRAIN "F_T"	HORIZONTAL SHEAR "F_V"	COMPRESSION PERPENDICULAR TO GRAIN "$F_{c\perp}$"	COMPRESSION PARALLEL TO GRAIN "F_c"	MODULUS OF ELASTICITY "E"
STRUCTURAL FRAMING							
NO.1	2" TO 4" THICK	**1550**	**950**	**70**	**320**	**1200**	**1,400,000**
		1500	*1000*	*95*	*625*	*1650*	*1,700,000*
		1300	650	70	425	1250	1,400,000
NO.2	2" TO 4" WIDE	**1300**	**775**	**65**	**320**	**1050**	**1,300,000**
		1300	*850*	*95*	*625*	*1500*	*1,600,000*
		---	---	---	---	---	---
NO.3	NOTE: GRADES FOR SPRUCE-PINE-FIR ARE NO.1/NO.2 AND NO.3	**700**	**450**	**65**	**320**	**625**	**1,100,000**
		750	*500*	*95*	*625*	*850*	*1,400,000*
		750	375	70	425	725	1,200,000
STUD		**750**	**450**	**65**	**320**	**625**	**1,100,000**
		750	*500*	*95*	*625*	*850*	*1,400,000*
		750	350	70	425	700	1,200,000
LIGHT FRAMING							
CONSTRUCT	2" TO 4" THICK	**975**	**575**	**65**	**320**	**1100**	**1,100,000**
		1000	*650*	*95*	*625*	*1600*	*1,500,000*
		975	475	70	425	1350	1,300,000
STANDARD	4" WIDE	**550**	**325**	**65**	**320**	**850**	**1,100,000**
		550	*375*	*95*	*625*	*1350*	*1,400,000*
		550	275	70	425	1100	1,200,000
UTILITY		**250**	**150**	**65**	**320**	**625**	**1,100,000**
		275	*175*	*95*	*625*	*875*	*1,300,000*
		250	125	70	425	725	1,100,000
JOISTS AND PLANKS							
NO.1	2" TO 4" THICK	**1350**	**950**	**70**	**320**	**1300**	**1,400,000**
		1000	*675*	*95*	*625*	*1450*	*1,700,000*
		875	425	70	425	1100	1,400,000
NO.2	VALUES GIVEN HERE FOR 12" WIDTH ONLY	**1100**	**775**	**65**	**320**	**1100**	**1,300,000**
		875	*575*	*95*	*625*	*1300*	*1,600,000*
		---	---	---	---	---	---
NO.3	SEE NOTE UNDER FRAMING	**625**	**450**	**65**	**320**	**675**	**1,100,000**
		500	*325*	*95*	*625*	*750*	*1,400,000*
		500	250	70	425	625	1,200,000
STUD	6" WIDE	**700**	**450**	**65**	**320**	**675**	**1,100,000**
		675	*450*	*95*	*625*	*825*	*1,400,000*
		675	325	70	425	675	1,200,000
BEAMS AND STRINGERS							
NO.1	5" AND WIDER	**1200**	**600**	**65**	**320**	**725**	**1,100,000**
		1350	*675*	*85*	*625*	*925*	*1,600,000*
		900	450	65	425	625	1,300,000
N0.2	DEPTH ≥ WIDTH+2"	**775**	**325**	**65**	**320**	**400**	**1,100,000**
		875	*425*	*85*	*625*	*600*	*1,300,000*
		600	300	65	425	425	1,000,000

Table 6.7 expresses the strength of Alaskan White Spruce as a percentage of the Douglas-Fir/Larch and Spruce/Pine/Fir strengths; this table provides a simple way to compare the various species. As an example, Table 6.7 indicates Alaskan White Spruce has 90 to 95% of the bending strength of Douglas-Fir/Larch when data from the 1986 NDS is used for comparison.

TABLE 6.7: STRENGTH OF ALASKAN WHITE SPRUCE WITH RESPECT TO DOUGLAS FIR/LARCH AND SPRUCE/PINE/FIR

PROPERTY	APPROXIMATE STRENGTH OF ALASKAN WHITE SPRUCE WITH RESPECT TO (%):			
	1986 NDS		1991 NDS	
	DOUGLAS FIR/LARCH	SPRUCE/ PINE/FIR	DOUGLAS FIR/LARCH	SPRUCE/ PINE/FIR
BENDING "F_b"	90-95	125-140	90-100	100-130
TENSION PARALLEL TO GRAIN "F_T"	90-95	110-150	90-140	110-145
HORIZONTAL SHEAR "F_V"	70-75	90-100	70-75	90-100
COMPRESS. PERPEND. TO GRAIN "$F_{C\perp}$"	50	75	50	75
COMPRESS. PARALLEL TO GRAIN "F_C"	80-105	95-140	70-75	85-95
MODULUS OF ELASTICITY "E"	70-75	92-100	60-80	85-110

Using Table 6.7 it can be seen that with respect to the 1986 NDS, Alaskan White Spruce is slightly weaker than Douglas-Fir/Larch in bending, tension, and parallel compression, and a good deal weaker in shear and perpendicular compression (bearing strength). Also using the 1986 data, it can be seen that Alaskan White Spruce is in general stronger than the Spruce/Pine/Fir combination, with the exception of perpendicular compression strength.

These trends change slightly when using the 1991 NDS data; with regard to the 1991 NDS, Table 6.7 shows that Alaskan White Spruce is now about the same as Douglas-Fir/Larch in bending and tension, while staying weaker in all other strength categories. Also using the 1991 data, Alaskan White Spruce is stronger than the Spruce/Pine/Fir in all categories but compression parallel to the grain and perpendicular compression. As a result of the differences between the 1986 and the 1991 NDS editions, Alaskan White Spruce increases in bending strength relative to other species in the 1991 NDS, while losing relative strength in parallel compression. The other strength properties are not affected.

Regardless of the version of the NDS used, it at first appears that the Douglas-Fir/Larch is a superior material, as it exceeds Alaskan White Spruce in shear and bearing strengths, while equaling or exceeding it in all other areas. However, structural design is more frequently governed by the need to resist bending forces rather than shear forces or bearing forces; Douglas-Fir/Larch has no real advantage in the category of bending strength. Thus, in many instances, Alaskan White Spruce will be found to be useable as a direct replacement for Douglas-Fir/Larch. As the cost of Douglas-Fir/Larch brought into Alaska from the continental United States continues to increase, it makes economic sense to use Alaskan White Spruce produced within the state as a substitute for Douglas-Fir/Larch.

It is apparent that Alaskan White Spruce is superior to Spruce/Pine/Fir type lumber. Alaskan White Spruce is stronger than Spruce/Pine/Fir in bending and parallel compression. The Alaska White Spruce has equivalent shear and bearing strengths. As a result of the additional strength, Alaska White Spruce may be used more efficiently and economically in a construction situation than Spruce/Pine/Fir, as its higher design values can reduce the number of members needed. This results in savings due to the reduced lumber volume and simplified structure erection, making Alaskan White Spruce well worth considering.

CHAPTER 7: SUMMARY AND CONCLUSIONS

7.1 Summary

White Spruce (*Picea glauca*(Moench)Voss) is a softwood timber species with practically white heartwood and sapwood. The wood has a fine texture and can be worked easily (15). Its range of growth includes the Northeastern regions of the United States, the Midwestern states bordering the great lakes, and extends through a large part of Canada to the state of Alaska (16). White Spruce growing in Alaska is referred to herein as Alaskan White Spruce to distinguish it from spruce growing outside of Alaska. While of the same species as all White Spruce, it is believed the mechanical properties of Alaskan White Spruce are somewhat different from common White Spruce due to the environment and growing conditions in Alaska. This environment results in slow growth, which in turn results in wood with high density, and correspondingly high strength.

About 6.8 million acres of commercial grade Alaskan White Spruce timberland exists in Alaska (21). Current usage of Alaskan White Spruce includes the annual production of less than 20 million board feet of finished lumber (30), and estimated, unsubstantiated harvest of approximately 20 to 35 million board feet of wood exported as round logs and processed chips (9,23,39,40). Consumption of finished lumber within Alaska is much higher than local production of White Spruce lumber. It is estimated that about 100 million board feet of dimension lumber is consumed annually in Alaska (30); the vast majority of this timber is imported into Alaska from the contiguous U.S. and Canada.

Alaska White Spruce is believed to be well suited for use in construction. In order to demonstrate the worth of Alaskan White Spruce for engineering and construction purposes, it was necessary to develop allowable design properties for the timber, such that these properties could be compared with those of other timber species. This required a testing program by which forest sites around Alaska could be sampled, and tested using a nationally recognized testing methodology.

A testing series was developed using ASTM D245 entitled "Standard Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber", and ASTM Document D143, entitled "Standard Methods of Testing Small Clear Specimens of Timber." The guidelines and specifications contained within these documents were modified where necessary to accommodate the testing of Alaskan White Spruce, and to allow the incorporation of modern, semi-automated testing equipment.

The test equipment developed uses a hydraulically operated loading frame manufactured by MTS inc., and includes electronic load and displacement transducers. These transducers allow the test data to be collected using a digital computer. This system allows for large volumes of highly accurate, consistent data to be collected with little or no operator induced error. Furthermore, the equipment set up allows a relatively high rate of sample testing. This system works very well; timber tests performed using the equipment and associated procedures have less variation and more consistency than other data reported in the literature.

The first timber sample site tested in this study is in the Tanana Valley State Forest, and is referred to herein as the Birch Lake Sample Site; this site is described in Alaska State Timber Sale #NC 788. This sale contains approximately

160 acres of timber, and is located at mile 304 Richardson Highway, near Birch Lake. For the testing reported herein, thirty Alaskan White Spruce trees were harvested from this site and processed into test specimens.

Using ASTM procedures and equipment developed during this project, a total of approximately 1600 specimens were tested. Test types included the following: Static Bending, Compression Parallel to Grain, Compression Perpendicular to Grain, Hardness, Shear Parallel to Grain, Cleavage, Tension Perpendicular to Grain, Nail Withdrawal, Specific Gravity and Shrinkage in Volume, and Radial and Tangential Shrinkage.

Data from the testing procedures was analyzed and reduced using mathematical and statistical procedures dictated by ASTM. The analysis included fitting standard probability distribution functions to the test results, and the subsequent determination of the 5% exclusion limits and mean values.

Using the results of the statistical analysis outlined by ASTM, allowable design properties for the Alaskan White Spruce collected from the Birch Lake sample site were developed. The properties were developed using NELMA and WWPA grading rules, such that the resulting values could be compared with existing allowable design properties for other species of lumber, particularly those which are currently imported into Alaska from the contiguous United States and Canada. These comparisons indicate that Alaskan White Spruce is comparable in strength and stiffness properties. As such, Alaskan White Spruce is suitable for use in engineering design and construction.

7.2 Conclusions

Alaskan White Spruce is a high strength timber material that is suitable for use in construction and engineering projects. Data collected during the course of this project indicates that it is comparable in strength and serviceability to Douglas-Fir/Larch, one of the most commonly used lumber species. It is superior in strength to many other softwood species. As such, Alaskan White Spruce is a good choice for many local timber uses currently being filled with imported Douglas-Fir/Larch and Spruce/Pine/Fir lumbers from the contiguous U.S. and Canada. There is no reason why properly manufactured Alaskan White Spruce lumber cannot be used to satisfy the needs of lumber users within the state.

Alaska has large amounts of Alaskan White Spruce which may be harvested on a continuous, sustained yield basis with proper management. Total forest acreage in interior Alaska is estimated at approximately 106 million acres, with some 13.5 million acres classified as commercial timberlands capable of producing more than 20 cubic feet of timber per year (21). Alaskan White Spruce accounts for 50 percent of this timberland, or about 6.8 million acres, including both available and reserved lands (21). This acreage can produce an estimated 100 million cubic feet of timber yearly, using a conservative production rate of 15 cubic feet/acre/year. This is sufficient to manufacture as much as 400 million board feet of value-added lumber product per year, using a ratio of four board feet per cubic foot (42). While much of the Alaskan White Spruce is not readily accessible, development of 25% of the spruce timberland would be sufficient to satisfy the 100 million board foot annual consumption of imported lumber within Alaska (30). Additional development of the spruce timberland could be used to provide finished timber products for export to the contiguous United States or foreign markets.

Currently, the majority of Alaska's timber production is sold as round logs--as raw material destine for manufacturing markets outside of Alaska, not as a valuable finished product manufactured in Alaska. Less than 20 million board feet of finished Alaskan White Spruce lumber is currently produced within Alaska, all of which is consumed within regional markets (30,33).

Increased production of manufactured Alaskan White Spruce lumber would serve to supply Alaska and other markets with high quality, high strength building material, while providing jobs and income for the citizens of the State of Alaska. Increased state income allows for the expansion of the Alaskan economy, and continued funding of state research and capital projects.

Alaska's economy is currently based largely on consumptive industry fueled by the exporting of raw materials. A move towards a sustainable lumber manufacturing industry would allow more effective utilization of Alaska's natural resources, and more economic return to the state and its people. One avenue to achieving this goal is by increasing the utilization of finished Alaskan White Spruce lumber.

7.3 Recommendations

To aid in an increased acceptance of Alaskan White Spruce as a viable construction material, the following items are suggested:

1. The design values developed during this project for the Birch Lake sample site are recommended here for adoption as design values for Alaskan White Spruce lumber from the Tanana Valley region, and as interim design values for Alaskan White Spruce in general, until such time as other testing programs suggest modifications to the design values. Note that these values apply mainly to lumber accurately graded using NELMA or WWPA rules.

2. It is recommended that sampling and testing of sites encompassing Alaska's harvestable White Spruce forests be continued, in a fashion similar to that developed and utilized during this study. Such a sampling would collect data showing the variation of Alaskan White Spruce properties with geographical area and growing environment. This allows design values to be developed for Alaskan White Spruce in general, and not just for specific forest regions. The data from the various sample sites would be combined into a composite data set using the procedure of ASTM D2555.

It is suggested the following sites be included in future Alaskan White Spruce testing: Susitna Block, Kenai Peninsula, and possibly the Yukon River and Copper River Basins.

3. It is recommended that a set of grading rules and inspection standards be developed specifically for use in Alaska. The "Alaska Grading Rule" would best be created as a modification of an existing rule such as NELMA or WWPA, with changes made to reflect the differences in timber species and

manufacturing conditions between Alaska and the remainder of the United States. For, NELMA and WWPA rules and associated strength reductions may be applied to timbers as wide as 24 inches with knots up to 12 inch diameter. Alaskan White Spruce is unlikely to produce timbers or defects of this size, and thus should not be subjected to the strength penalties incorporated into NELMA and WWPA rules.

A major move towards acceptance of Alaskan White Spruce by the construction and engineering communities can not be made until the State of Alaska develops an "Alaska Grading Rule".

4. It is recommended that incentives be put in place to encourage the use and development of Alaskan White Spruce, and that current incentives be continued. Incentives may take many forms: financial support for fledgling lumber manufacturers, requirements for use of local building materials on public works projects, subsides for land and environmental improvements during the course of logging operations, creation of additional state forests and the increased availability of timber sales and assistance from the Alaska Department of Forestry.

5. It is necessary for the state and developers of timber resources to realize than land in Alaska is multiple use land. Alaskan lands provide for timber harvests, wildlife management, recreational usage, and support of tourism; all of these are vital to the state's economy. In order that all of the users of Alaskan land be supported and protected, and to ensure a continuous harvest of Alaskan White Spruce, it is recommended that the state make efforts to expand its timber lands management efforts. The areas of sustainable annual yield, reforestation, fire control, erosion, and logging aesthetics will always need to be addressed.

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APPENDIX A: EXAMPLES OF DATA FILES AND TEST REPORTS

Several types of computer files were used during this study, due to the nature of the electronically collected data. Examples A.1 and A.2 are examples of typical data files generated during a mechanical test procedure, as described in Section 4.3. Both examples consist of a "header" section containing the default testing parameters, and the test information input by the operator and a "listing" section, containing the collected data points. Example A.1 is of a raw data file, with the load and deflection information presented as voltage data collected from the analog-to-digital convertor unit. Example A.2 is a similar file, although here the load and deflection data has been converted into physical units of force and length using calibration equations. Both files are generated by the software which runs the testing equipment.

Further processing of the information in the *.DAT files is needed to extract the desired mechanical properties values for the individual test results. This processing is done using computerized spreadsheet software which has been set up to determine maximum loads, proportional limits, modulus of elasticity and other mechanical property values as described in Section 5.2. The spreadsheet prints out the results of the data processing in the form of a report form.

Examples A.3 through A.11 are examples of each of test report forms used during this project. Many of these report forms include a sketch of the sample geometry used in each particular test. These sketches are used for recording the shape of the failed specimens. The report forms for tests which record load versus deflection data include a plot of the collected data which shows the linear line fitted to the data and the proportional limit as determined by the spreadsheet using the procedures described in Section 5.2.

EXAMPLE A.1: TYPICAL *.RAW DATA FILE
FOR MECHANICAL PROPERTIES TESTING

```
"SAMPLE.TIME"         0
"START.CHAN%"         0
"END.CHAN%"           5
"TRIG.SOURCE%"        0
"GAIN%"               1
"INTERVAL%"           1
"SLOPE.CHAN(1)"       1
"SLOPE.CHAN(2)"       .5
"SLOPE.CHAN(3)"       1
"SLOPE.CHAN(4)"       1
"SLOPE.CHAN(5)"       .192
"TEST.TYPE$"          "STATIC BENDING"
"TEST.LOC$"           "U.A.F."
"DATE"                "10-15-1993"
"MACHINE.NUMBER%"     458
"SPECIES$"            "AK WHITE SPRUCE"
"SEASONING$"          ""
"SHIP.NUMBER%"        1
"SAMPLE.CODES$"       "1_45_N4D"
"LOADING.TYPE$"       "CENTER"
"LOADING.SPAN"        28.01
"LOADING.RATE"        .1
"SAMPLE.HEIGHT"       1.971
"SAMPLE.WIDTH"        1.969
"SAMPLE.LENGTH"       30.062
"SAMPLE.WEIGHT"       850
"RING.COUNT"          22
"SAPWOOD"             0
"SUMMERWOOD"          15
"TEMPERATURE"         72
"HUMIDITY"            50
"FAILURE.MODE$"       "TO BE ADDED LATER"
"MAX.LOAD"            0
"DEFLECTION.MAX"      0
"ELASTIC.LOAD"        0
"DEFLECTION.ELASTIC"0
"OPERATOR$"           "DEAN SYTA"
```

EXAMPLE A.1, CONTINUED:

TIME (SEC)	LOAD (VOLTS)	DEFLECTION (VOLTS)	STROKE (VOLTS)
0	-6.19E-02	9.252014	4.999084
1	-6.95E-02	9.250488	4.996338
2	-7.41E-02	9.248657	4.992981
3	-8.23E-02	9.2453	4.989319
4	-9.12E-02	9.240112	4.985962
5	-.1025391	9.234314	4.9823
6	-.1126099	9.22821	4.979858
7	-.1245117	9.221802	4.976196
8	-.1345825	9.214172	4.972839
9	-.1449585	9.207764	4.969177
10	-.15625	9.20166	4.966736
11	-.1681519	9.194336	4.963074
12	-.178833	9.187927	4.960022
13	-.1904297	9.179993	4.957275
14	-.2017212	9.173279	4.953308
15	-.213623	9.16687	4.950562
16	-.223999	9.159851	4.946899
17	-.2359009	9.152222	4.942627
18	-.2478027	9.145508	4.93988
19	-.2600098	9.138489	4.936829
20	-.2722168	9.131165	4.933167
21	-.2835083	9.125366	4.930725
22	-.2941895	9.118042	4.927979
23	-.3060913	9.111023	4.923401
24	-.3186035	9.103394	4.920654
25	-.329895	9.096375	4.917297
26	-.3414917	9.089661	4.914246
27	-.3536987	9.081726	4.910278
28	-.3649902	9.075012	4.906311
29	-.3759766	9.067078	4.90387
30	-.3887939	9.060364	4.900513
31	-.4003906	9.05304	4.897156
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.
367	-.1950073	6.037903	3.789063
368	-.2078247	6.029053	3.785095
369	-.213623	6.020508	3.782349
370	-.2166748	6.011353	3.778992
371	-.2209473	6.002197	3.77594

EXAMPLE A.2: TYPICAL *.DAT DATA FILE
FOR MECHANICAL PROPERTIES TESTING

```
"SAMPLE.TIME"          0
"START.CHAN%"          0
"END.CHAN%"            5
"TRIG.SOURCE%"         0
"GAIN%"                1
"INTERVAL%"            1
"SLOPE.CHAN(1)"        1
"SLOPE.CHAN(2)"        .5
"SLOPE.CHAN(3)"        1
"SLOPE.CHAN(4)"        1
"SLOPE.CHAN(5)"        .192
"TEST.TYPE$"           "STATIC BENDING"
"TEST.LOC$"            "U.A.F."
"DATE"                 "10-15-1993"
"MACHINE.NUMBER%"      458
"SPECIES$"             "AK WHITE SPRUCE"
"SEASONING$"           ""
"SHIP.NUMBER%"         1
"SAMPLE.CODES$"        "1_45_N4D"
"LOADING.TYPE$"        "CENTER"
"LOADING.SPAN"         28.01
"LOADING.RATE"         .1
"SAMPLE.HEIGHT"        1.971
"SAMPLE.WIDTH"         1.969
"SAMPLE.LENGTH"        30.062
"SAMPLE.WEIGHT"        850
"RING.COUNT"           22
"SAPWOOD"              0
"SUMMERWOOD"           15
"TEMPERATURE"          72
"HUMIDITY"             50
"FAILURE.MODE$"        "TO BE ADDED LATER"
"MAX.LOAD"             1663.208
"DEFLECTION.MAX"       .4869081
"ELASTIC.LOAD"         0
"DEFLECTION.ELASTIC"0
"OPERATOR$"            "DEAN SYTA"
```

EXAMPLE A.2, CONTINUED:

TIME (SEC)	LOAD (POUNDS)	DEFLECTION (INCHES)	STROKE (INCHES)
0	0	0	0
1	3.814697	4.307368E-03	-1.373291E-03
2	6.103516	4.662516E-03	-3.051758E-03
3	10.22339	5.313624E-03	-4.882813E-03
4	14.64844	6.319889E-03	-6.561279E-03
5	20.29419	7.44455E-03	-8.392334E-03
6	25.32959	8.628417E-03	-9.613037E-03
7	31.28052	9.871491E-03	-1.144409E-02
8	36.31592	1.135136E-02	-1.312256E-02
9	41.50391	1.259447E-02	-1.495361E-02
10	47.14966	1.377839E-02	-1.617432E-02
11	53.10059	1.519912E-02	-1.800537E-02
12	58.44116	1.644227E-02	-1.953125E-02
13	64.2395	1.798143E-02	-2.090454E-02
14	69.88525	1.928381E-02	-2.288818E-02
15	75.83618	2.052701E-02	-2.426147E-02
16	81.02417	2.188862E-02	-2.609253E-02
17	86.9751	2.336866E-02	-2.822876E-02
18	92.92603	2.467111E-02	-2.960205E-02
19	99.02954	2.603277E-02	-3.112793E-02
20	105.1331	2.745366E-02	-3.295898E-02
21	110.7788	2.857854E-02	-3.417969E-02
22	116.1194	2.999946E-02	-3.555298E-02
23	122.0703	3.136119E-02	-.0378418
24	128.3264	3.284135E-02	-3.921509E-02
25	133.9722	3.420312E-02	-4.089355E-02
26	139.7705	3.550569E-02	-4.241943E-02
27	145.874	3.704511E-02	-4.440308E-02
28	151.5198	3.834771E-02	-4.638672E-02
29	157.0129	3.988717E-02	-4.760742E-02
30	163.4216	4.118981E-02	-4.928589E-02
31	169.22	4.261089E-02	-5.096436E-02
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.
361	1654.663	.4825825	-.5950928
362	1657.41	.4838861	-.5967712
363	1660.156	.4854268	-.5982971
364	1663.208	.4869081	-.6002808
365	1570.129	.4899893	-.6016541
366	1573.944	.4914707	-.6034851
367	66.52832	.6280468	-.605011
368	72.93701	.6297635	-.6069946

EXAMPLE A.3: TYPICAL STATIC BEAM TEST REPORT

STATIC BEAM BENDING TEST
UNIVERSITY OF ALASKA, FAIRBANKS

SAMPLE #: 1_15_S3A TEST DATA: 03-03-1992 SPECIES: AK WHITE SPRUCE

TESTING EQUIPMENT DATA

TEST TYPE:	STATIC BENDING	TEST MACHINE:	458	
LOADING:	CENTER	TESTING SPEED:	.1	in/min
SPAN:	28.01			

TEST SPECIMEN DATA

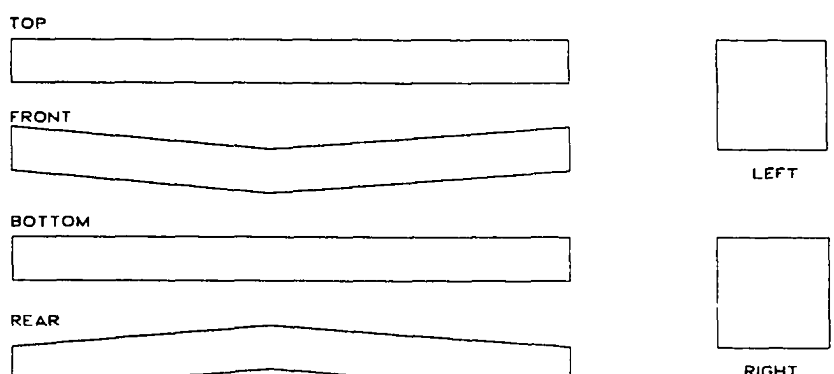
HEIGHT:	2.002	in.	LENGTH:	60.062	in.
WIDTH:	2.004	in.	WEIGHT:	868	gm.
RINGS PER INCH:	28	/in.	SAPWOOD:	5	%
SEASONING:	SEASONED		SUMMERWOOD:	10	%
MOISTURE:	15.15	%	TEMPERATURE:	72	F
TESTED BY:	DEAN SYTA		HUMIDITY:	20	%

TEST RESULTS

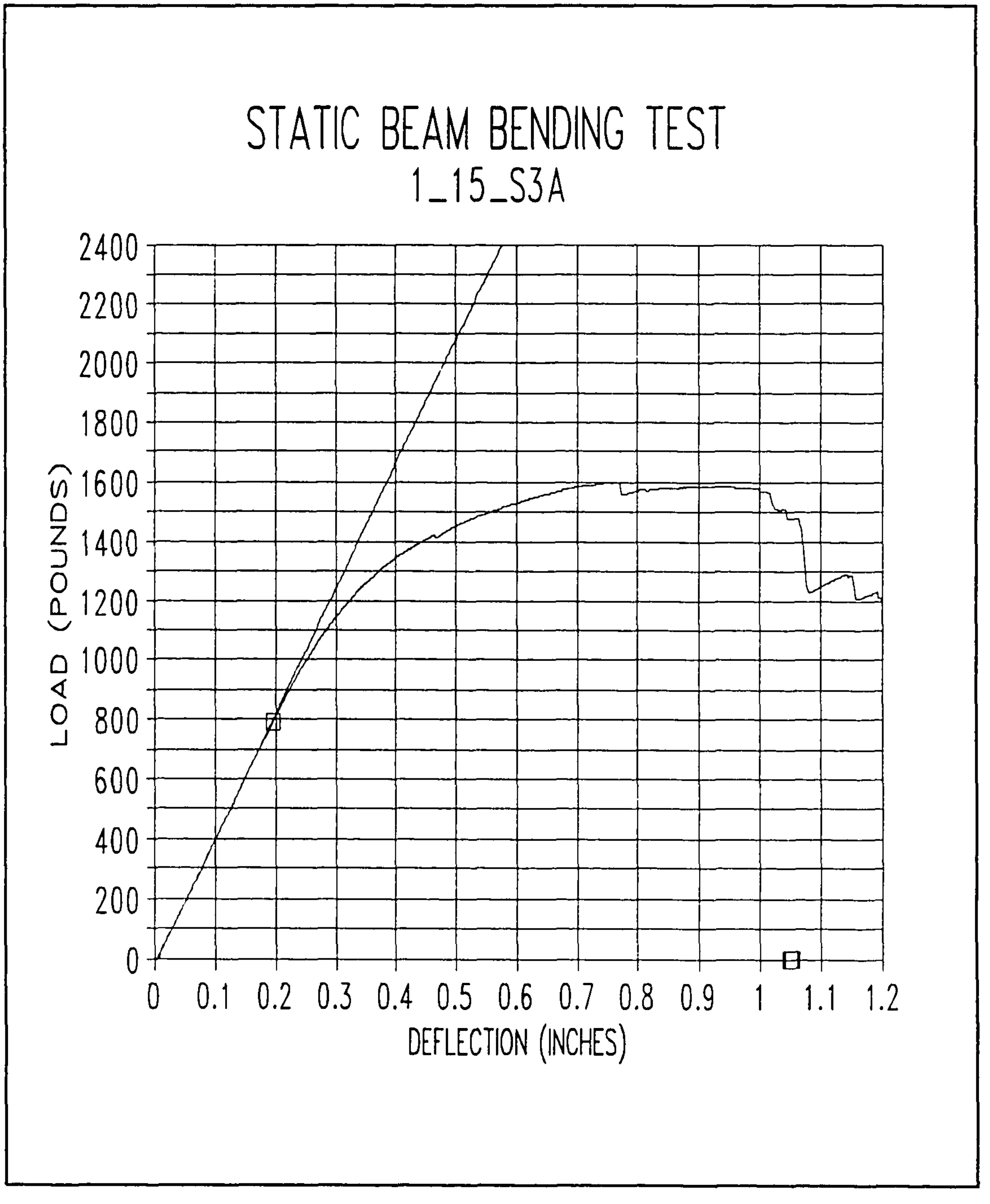
MAX.LOAD:	1601.56	lbs.	DEFLECT AT MAX:	.7547	in.
LOAD AT P.L.:	791.02	lbs.	DEFLECT AT P.L.	.1948	in.
FAILURE TYPE:	SPLINTERING TENSION				

SLOPE OF ELASTIC LINE:	4196.548	lbs/in
LINE INTERCEPT:	-18.9601	lbs.
CORRELATION COEFFICIENT:	.99991	
MOD. OF RUPTURE	8377.66	psi.
MOD. OF ELASTICITY	1433777	psi.
EXCLUSION FLAG:	NO	

SKETCH



EXAMPLE A.3 CONTINUED:



EXAMPLE A.4: TYPICAL PARALLEL COMPRESSION TEST REPORT

PARALLEL COMPRESSION TEST
UNIVERSITY OF ALASKA, FAIRBANKS

SAMPLE #: 1_22_S3G TEST DATA: 03-26-1993 SPECIES: AK WHITE SPRUCE

TESTING EQUIPMENT DATA

TEST TYPE:	PARALLEL COMPRESSION	TEST MACHINE:	458	
LOADING:	AXIAL	TESTING SPEED:	.024	in/min
GAGE LENGTH:	28.01			

TEST SPECIMEN DATA

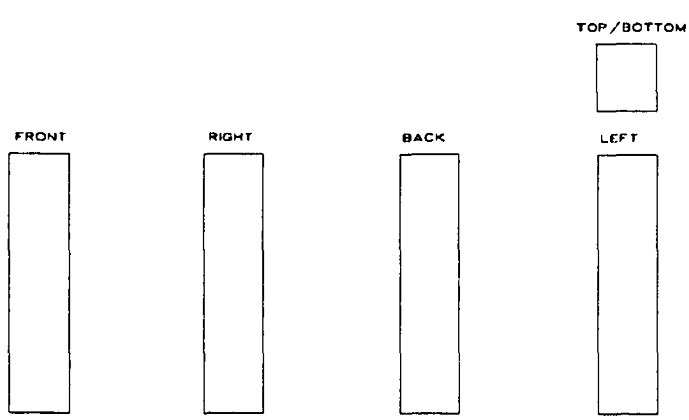
DEPTH:	1.992	in.	LENGTH:	7.02	in.
WIDTH:	1.990	in.	WEIGHT:	220.1	gm.
RINGS PER INCH:	28	/in.	SAPWOOD:	0	%
SEASONING:	SEASONED		SUMMERWOOD:	15	%
MOISTURE:	13.67	%	TEMPERATURE:	72	F
TESTED BY:	DEAN SYTA		HUMIDITY:	20	%

TEST RESULTS

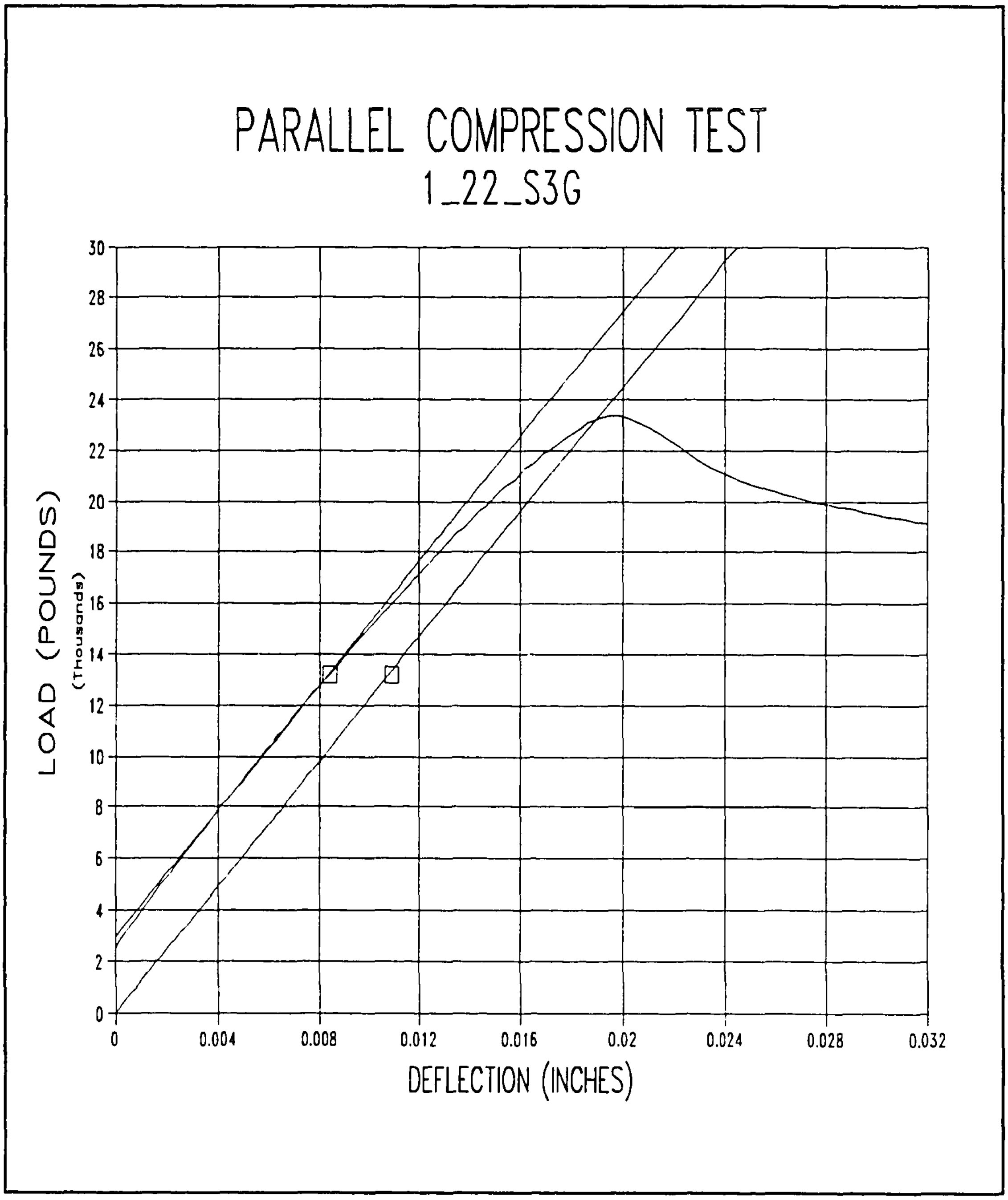
MAX.LOAD:	23371.89 lbs.	DEFLECT AT MAX:	.01951	in.
LOAD AT P.L.:	11004.64 lbs.	DEFLECT AT P.L.	.00863	in.
FAILURE TYPE:	CRUSHING IN MIDDLE			

SLOPE OF ELASTIC LINE:	1275924	lbs/in
LINE INTERCEPT:	2711.776	lbs.
CORRELATION COEFFICIENT:	.999732	
MOD. OF RUPTURE	5895.9	psi.
MOD. OF ELASTICITY	1927045	psi.
EXCLUSION FLAG:	NO	

SKETCH



EXAMPLE A.4, CONTINUED:



EXAMPLE A.5: TYPICAL PERPENDICULAR COMPRESSION TEST REPORT

PERPENDICULAR COMPRESSION TEST
UNIVERSITY OF ALASKA, FAIRBANKS

SAMPLE #: 1_21_S1A TEST DATA: 09-08-1992 SPECIES: AK WHITE SPRUCE

TESTING EQUIPMENT DATA

TEST TYPE:	PERPENDICULAR COMPRESSION	TEST MACHINE:	458
LOAD PLATE:	1.998 IN.	TESTING SPEED:	.012 in/min

TEST SPECIMEN DATA

HEIGHT:	1.984	in.	LENGTH:	5.9705	in.
WIDTH:	2.002	in.	WEIGHT:	202.5	gm.
RINGS PER INCH:	30	/in.	SAPWOOD:	0	%
SEASONING:	GREEN		SUMMERWOOD:	7	%
MOISTURE:	39.9	%	TEMPERATURE:	68	F
TESTED BY:	DEAN SYTA		HUMIDITY:	48	%

TEST RESULTS

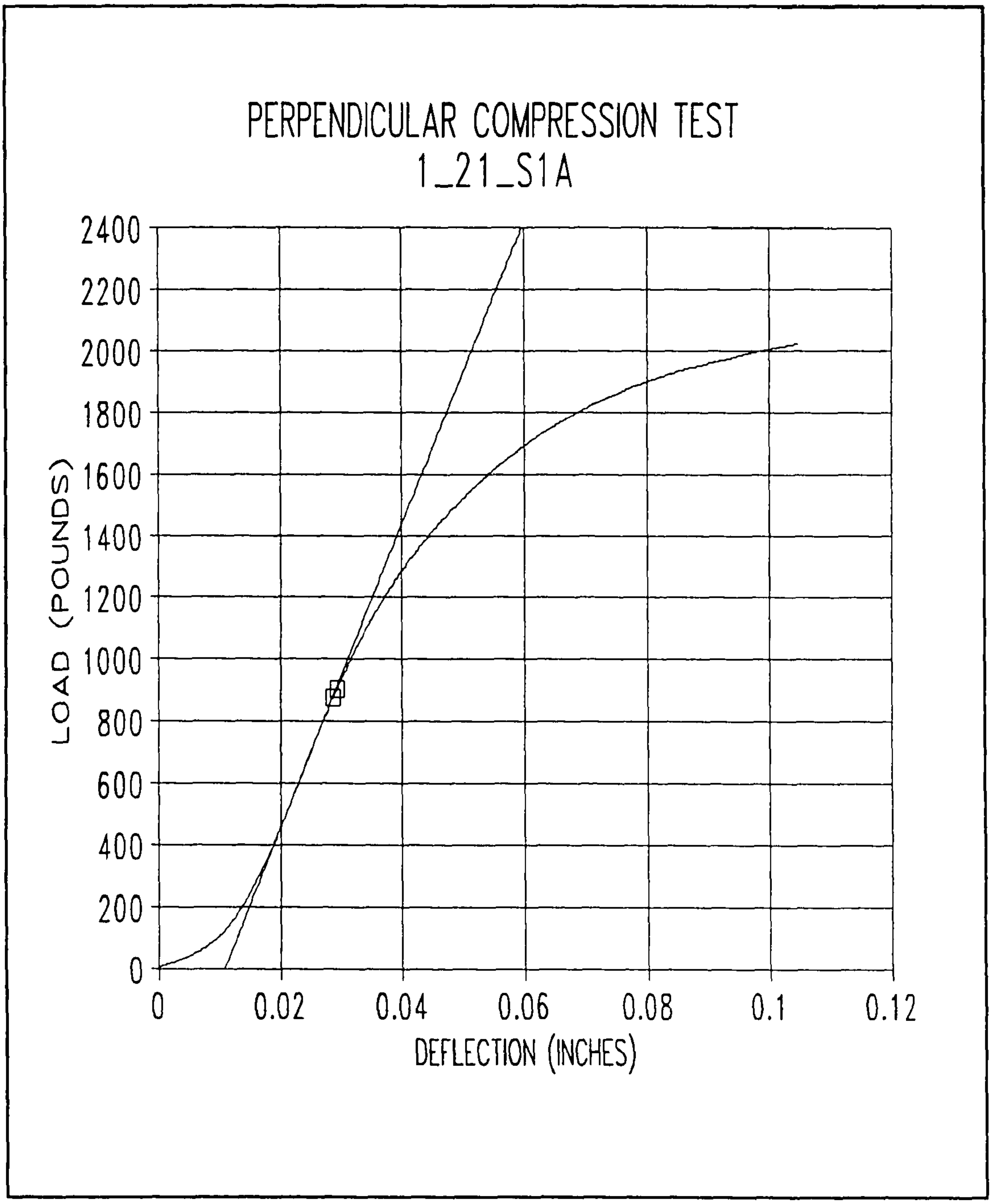
LOAD AT .1":	2003.9379 lbs.	LOAD AT P.L.:	902.40	in.
		DEFLECT AT P.L.	.02938	in.

FAILURE TYPE:

STRESS AT P.L.:	225.6014	psi.
STRAIN AT P.L.:	.01481	
SLOPE OF ELASTIC LINE:	49102.03	lbs/in
LINE INTERCEPT:	-529.022	lbs.
CORRELATION COEFFICIENT:	.999641	
MOD. OF ELASTICITY	24354.63	psi.
EXCLUSION FLAG:	NO	

SKETCH

EXAMPLE A.5, CONTINUED:



EXAMPLE A.6: TYPICAL PARALLEL TENSION TEST REPORT

PARALLEL TENSION TEST
UNIVERSITY OF ALASKA, FAIRBANKS

SAMPLE #: 1_11_N4I TEST DATA: 07-28-1993 SPECIES: AK WHITE SPRUCE

TESTING EQUIPMENT DATA

TEST TYPE:	PARALLEL TENSION	TEST MACHINE:	458	
LOADING:	PARALLEL	TESTING SPEED:	.05	in/min
GAGE LENGTH:	2 IN.			

TEST SPECIMEN DATA

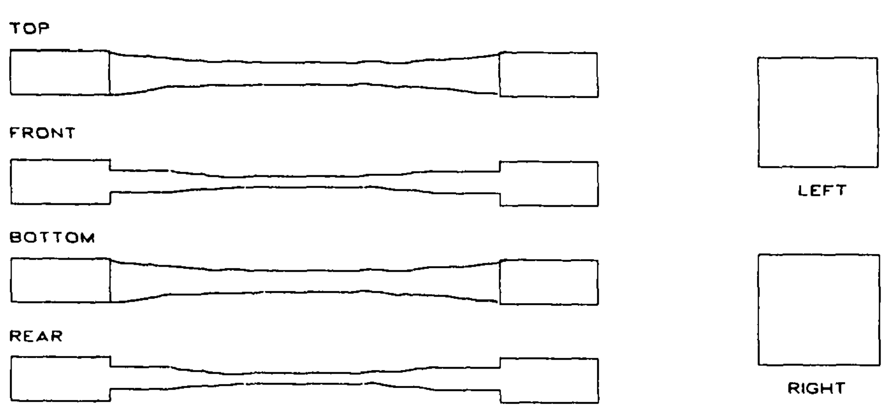
DEPTH:	.1830	in.	LENGTH:	2.5	in.
WIDTH:	.3185	in.	WEIGHT:	75.8	gm.
RINGS PER INCH:	34	/in.	SAPWOOD:	0	%
SEASONING:	SEASONED		SUMMERWOOD:	15	%
MOISTURE:	10.43	%	TEMPERATURE:	75	F
TESTED BY:	DEAN SYTA		HUMIDITY:	52	%

TEST RESULTS

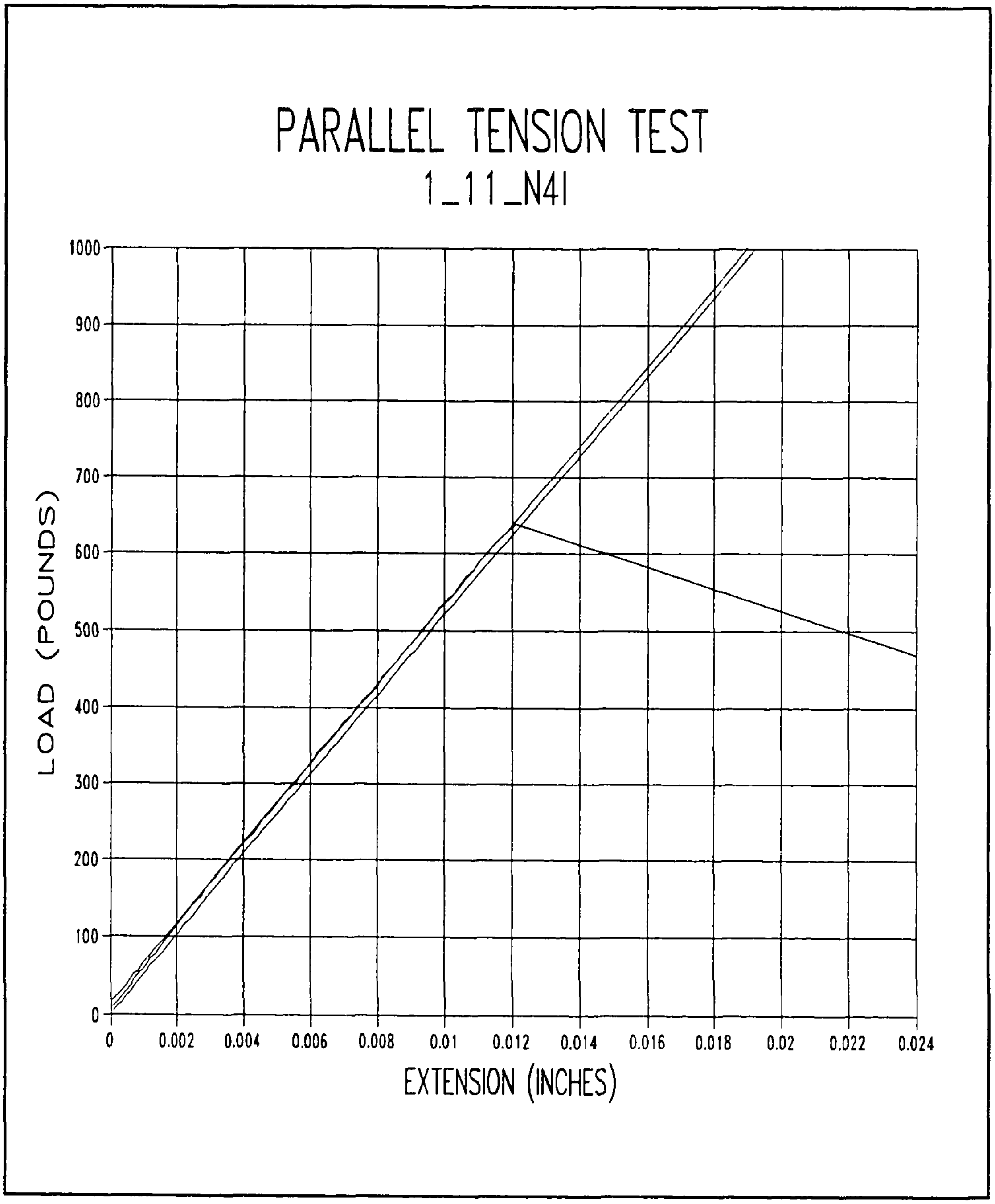
MAX.LOAD:	639.64	lbs.	DEFLECT AT MAX:	.01209	in.
LOAD AT P.L.:	0	lbs.	DEFLECT AT P.L.	0	in.
FAILURE TYPE:	BRASH TENSION	NOTE: SAMPLE APPEARS TO HAVE ROT			

SLOPE OF ELASTIC LINE:	52012.49	lbs/in
LINE INTERCEPT:	14.2684	lbs.
CORRELATION COEFFICIENT:	.999819	
TENSILE STRENGTH	10974.4	psi.
MOD. OF ELASTICITY	1784749	psi.
EXCLUSION FLAG:	YES	

SKETCH



EXAMPLE A.6, CONTINUED:



EXAMPLE A.7: TYPICAL SHEAR PARALLEL TO GRAIN TEST REPORT

SHEAR PARALLEL TO GRAIN TEST
UNIVERSITY OF ALASKA, FAIRBANKS

SAMPLE #: T_15_E3C TEST DATA: 06-18-1993 SPECIES: AK WHITE SPRUCE

TESTING EQUIPMENT DATA

TEST TYPE:	DOUBLE SHEAR TEST	TEST MACHINE:	458
		TESTING SPEED:	.1 in/min

TEST SPECIMEN DATA

SHEAR SURFACE:	TAN	SEASONING:	SEASONED
WIDTH:	2.002 in.	MOISTURE:	11.34 %
LENGTH 1:	1.265 in.	TEMPERATURE:	72 F
LENGTH 2:	1.259 in.	HUMIDITY:	60 %
TESTED BY:	DEAN SYTA		

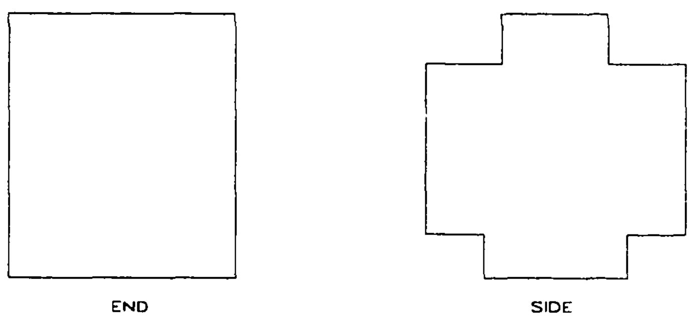
TEST RESULTS

MAX.LOAD:	4514.47 lbs.	SHEAR STRENGTH:	983.41 psi.
SHEAR AREA:	5.0530		

REMARKS: TYPICAL GROWTH

EXCLUSION FLAG: NO

SKETCH



EXAMPLE A.8: TYPICAL PERPENDICULAR TENSION TEST REPORT

PERPENDICULAR TENSION TEST
UNIVERSITY OF ALASKA, FAIRBANKS

SAMPLE #: R_10_N4D TEST DATA: 06-03-1993 SPECIES: AK WHITE SPRUCE

TESTING EQUIPMENT DATA

TEST TYPE:	PERPENDICULAR TENSION	TEST MACHINE:	458
		TESTING SPEED:	.1 in/min

TEST SPECIMEN DATA

TENSION SURFACE:		RAD	SEASONING:	SEASONED	
WIDTH:	1.997	in.	MOISTURE:	11.08	%
LENGTH:	.9935	in.	TEMPERATURE:	75	F
TESTED BY:	DEAN SYTA		HUMIDITY:	45	%

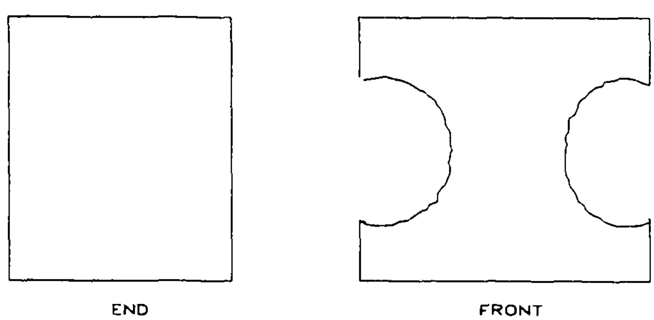
TEST RESULTS

MAX.LOAD: 757.904 lbs. TENSILE STRENGTH: 382.00 psi.

REMARKS: TYPICAL GROWTH

EXCLUSION FLAG: NO

SKETCH



EXAMPLE A.9: TYPICAL CLEAVAGE TEST REPORT

CLEAVAGE TEST
UNIVERSITY OF ALASKA, FAIRBANKS

SAMPLE #: T_10_N3D TEST DATA: 11-05-1992 SPECIES: AK WHITE SPRUCE

TESTING EQUIPMENT DATA

TEST TYPE:	CLEAVAGE TEST	TEST MACHINE:	458	
		TESTING SPEED:	.1	in/min

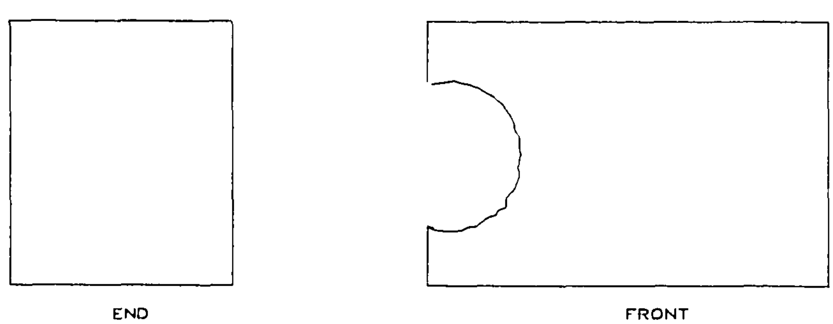
TEST SPECIMEN DATA

TENSION SURFACE:		TAN	SEASONING:	GREEN	
WIDTH:	1.951	in.	MOISTURE:	94.43	%
LENGTH:	3.038	in.	TEMPERATURE:	74	F
TESTED BY:	DEAN SYTA		HUMIDITY:	52	%

TEST RESULTS

MAX.LOAD:	285.1868 lbs.	LOAD PER INCH: OF WIDTH.	146.17 psi.
REMARKS:	OUTER GROWTH		
EXCLUSION FLAG:	NO		

SKETCH



EXAMPLE A.10: TYPICAL HARDNESS TEST REPORT

HARDNESS TEST
UNIVERSITY OF ALASKA, FAIRBANKS

SAMPLE #: 1_11_S2C TEST DATA: 06-28-1993 SPECIES: AK WHITE SPRUCE

TESTING EQUIPMENT DATA

TEST TYPE:	HARDNESS TEST	TEST MACHINE:	458	
LOADING:	.4375 BALL PROD	TESTING SPEED:	.25	in/min
DEPTH:	.222 in.			

TEST SPECIMEN DATA

HEIGHT:	1.999	in.	SEASONING:	SEASONED	
WIDTH:	2.008	in.	MOISTURE:	10.73	%
LENGTH:	5.03	in.	TEMPERATURE:	72	F
WEIGHT:	145.6	gm.	HUMIDITY:	58	%
RINGS PER INCH:	28	/in.	SAPWOOD:	0	%
TESTED BY:	DEAN SYTA		SUMMERWOOD:	15	%

TEST RESULTS

	FACE1		FACE 2		AVERAGE	
RADIAL	552.97	lbs.	528.72	lbs.	540.84	lbs.
TANGENTIAL	438.53	lbs.	560.76	lbs.	499.65	lbs.
END	677.03	lbs.	356.29	lbs.	516.66	lbs.

RADIAL AND TANGENTIAL AVERAGE: 520.24 lbs.

FAILURE NOTES:

EXCLUSION FLAG: NO

SKETCH

EXAMPLE A.11: TYPICAL NAIL WITHDRAWAL TEST REPORT

NAIL WITHDRAWAL TEST
UNIVERSITY OF ALASKA, FAIRBANKS

SAMPLE #: 1_29_E3C TEST DATA: 07-02-1993 SPECIES: AK WHITE SPRUCE

TESTING EQUIPMENT DATA

TEST TYPE:	NAIL EXTRACTION TEST	TEST MACHINE:	458
LOADING:	6D BRIGHT BOX	TESTING SPEED:	.075 in/min
DEPTH:	1.25 in.		

TEST SPECIMEN DATA

HEIGHT:	2.004	in.	SEASONING:	SEASONED	
WIDTH:	2.008	in.	MOISTURE:	11.27	%
LENGTH:	4.229	in.	TEMPERATURE:	75	F
WEIGHT:	126.7	gm.	HUMIDITY:	55	%
RINGS PER INCH:	30	/in.	SAPWOOD:	10	%
TESTED BY:	DEAN SYTA		SUMMERWOOD:	10	%

TEST RESULTS

	FACE 1		FACE 2		AVERAGE	
RADIAL	70.40	lbs.	70.55	lbs.	70.48	lbs.
TANGENTIAL	78.84	lbs.	95.85	lbs.	87.34	lbs.
END	55.19	lbs.	48.27	lbs.	51.73	lbs.

SPECIFIC GRAVITY, CALCULATED: .4085

FAILURE NOTES:

EXCLUSION FLAG: NO

SKETCH

APPENDIX B: SUMMARIES OF TEST DATA

This appendix contains mechanical property test results for the individual Alaskan White Spruce specimens tested during this project. These tests where performed on small, clear samples of wood using the equipment and procedures described in Chapter 4. The data tables given here where used as the basis for the statistical analysis discussed in Chapter 5, the results of which are presented in Appendix C and Appendix D.

In addition to the test results, the tables contain pertinent testing information, such as the sample number, sample dimensions and weight. The tables also include sample characteristics such as the percentage of summerwood present, the number of rings per inch, and the sample moisture content at the time of the test.

INDEX TO TABLES:

TEST TYPE	TABLE NUMBER	
	GREEN WOOD	SEASONED WOOD
Static Bending	B.1, B.2	B.3
Compression Parallel to Grain	B.4	B.5
Compression Perpendicular to Grain	B.6	B.7
Tension Parallel to Grain	N/A	B.8
Shear Strength	B.9	B.10
Perpendicular Tension	B.11	B.12
Cleavage	B.13	B.14
Hardness	B.15	B.16
Nail Withdrawal	B.17	B.18
Radial and Tangential Shrinkage	B.19	N/A
Specific Gravity and Shrinkage in Volume	B.20	N/A

TABLE B.1: STATIC BENDING DATA, GREEN WOOD, .2"/MIN

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_10_E4C	07-28-19	1.946	1.949	30.25	1369.6	90.18	26	80	20	72	58	1025.24	0.7801	417.02	0.1263	5836.22	1314611	NO
1_10_N1A	07-27-19	1.988	1.976	30.06	1088.1	32.90	28	0	15	72	60	1027.37	1.0092	372.92	0.1205	5527.30	1110362	NO
1_10_N3D	07-27-19	2.002	1.986	30.05	1427.4	102.38	22	60	25	71	66	963.29	0.8892	325.32	0.0970	5084.55	1167513	NO
1_10_N4C	08-03-19	2.005	1.996	30.13	1415.0	96.44	22	80	20	72	52	1036.07	0.7828	441.13	0.1197	5425.07	1296149	NO
1_10_N4E	07-29-19	2.008	2.017	30.19	1119.0	31.93	32	0	20	72	60	1082.92	0.8239	343.48	0.1061	5594.56	1115301	NO
1_10_S1C	07-27-19	1.996	1.983	30.03	1043.3	33.20	22	0	5	72	64	1054.99	0.8551	459.75	0.1402	5610.61	1177859	NO
1_10_S2B	07-30-19	1.743	1.985	30.08	916.1	31.43	24	0	20	72	59	794.22	1.0055	314.03	0.1452	5533.37	1161399	NO
1_10_W4A	07-23-19	1.994	1.989	29.87	1249.0	66.27	26	50	20	70	64	1005.71	0.8357	411.53	0.1092	5343.07	1313851	NO
1_11_E4C	08-03-19	2.007	2.009	30.15	1103.2	51.52	23	15	10	72	50	876.31	0.7838	316.77	0.1134	4549.76	958146	NO
1_11_S1C	08-04-19	1.822	1.921	30.13	852.5	32.00	28	0	15	72	55	738.22	0.7113	377.81	0.1621	4863.69	1139481	NO
1_11_S2D	07-31-19	2.013	2.004	29.88	970.3	33.87	13	0	10	72	65	947.72	1.2066	425.11	0.1463	4903.44	1012190	NO
1_11_W3D	07-27-19	2.009	1.980	30.01	959.8	32.47	26	0	20	72	59	984.34	0.6996	373.38	0.1010	5175.19	1287464	NO
1_12_E4A	07-22-19	1.991	1.960	30.12	944.5	33.26	31	0	30	75	51	950.78	0.8504	480.35	0.1352	5141.43	1269725	NO
1_12_N3D	08-05-19	1.992	1.998	30.03	1081.6	32.07	38	0	20	72	50	1129.61	0.6150	487.06	0.1332	5986.29	1314216	NO
1_12_N3L	08-05-19	1.997	2.000	29.98	1033.4	38.04	26	0	25	72	55	953.83	0.7911	348.05	0.1179	5024.44	1056980	NO
1_12_N4C	08-05-19	1.990	1.995	30.00	1069.1	31.01	32	0	20	72	57	1161.50	0.7961	420.99	0.1212	6176.95	1248677	NO
1_12_N4I	07-30-19	1.997	2.005	30.15	1058.1	33.12	20	0	35	72	61	1058.50	0.7197	334.78	0.1015	5561.93	1169815	NO
1_12_N4K	08-05-19	2.000	1.997	30.00	1065.7	37.04	24	0	25	72	52	919.04	0.8724	292.97	0.1093	4833.92	925471	NO
1_12_S3B	07-30-19	1.753	1.996	30.06	939.3	30.47	30	0	30	72	59	881.20	0.6511	381.47	0.1380	6036.04	1456710	NO
1_12_S3D	08-05-19	1.993	1.993	30.02	1074.8	34.35	24	0	35	72	52	1137.85	0.8074	386.20	0.1091	6039.02	1261481	NO
1_12_S3J	08-04-19	1.990	2.005	30.05	1131.7	58.56	28	20	20	72	58	972.60	0.8522	419.31	0.1326	5146.55	1138328	NO
1_12_S4C	08-05-19	1.994	1.990	30.13	1087.6	32.85	34	0	20	72	50	1162.57	0.8101	419.01	0.1176	6173.32	1318680	NO
1_12_S4G	07-28-19	1.581	2.010	30.02	785.9	34.10	28	15	15	72	56	676.73	0.8491	365.30	0.1882	5659.24	1405515	NO
1_12_S4I	07-31-19	2.002	2.022	27.88	1033.4	35.53	24	5	35	70	70	1031.04	0.6508	471.34	0.1444	5345.26	1141641	NO
1_12_S4K	08-05-19	1.995	1.999	30.00	1053.4	39.63	28	5	25	72	55	1049.04	1.0334	324.40	0.1051	5539.86	1098926	NO
1_12_S4L	07-24-19	1.990	1.982	30.06	1026.3	39.63	19	4	15	74	56	1007.23	0.9048	295.41	0.0925	5391.69	1119639	NO
1_12_W3J	07-30-19	1.999	2.005	30.00	1060.6	38.30	24	5	25	72	59	1037.14	0.7984	374.30	0.1094	5438.78	1216077	NO
1_14_N3D	07-28-19	2.013	2.010	29.70	965.9	37.37	28	10	15	72	58	995.79	0.7048	453.95	0.1276	5136.74	1240245	NO
1_14_S4C	07-28-19	2.006	2.014	30.06	1101.3	60.43	26	15	15	72	60	994.87	0.6570	447.69	0.1233	5157.64	1279982	NO
1_15_E3D	08-04-19	2.008	2.010	30.15	1060.1	32.92	26	0	20	72	56	1094.21	0.7662	315.86	0.0996	5672.58	1082451	NO
1_15_N4A	07-24-19	1.965	1.961	30.13	940.3	34.00	23	4	15	74	56	976.56	0.8189	276.79	0.0975	5418.78	1111878	NO
1_15_S1A	07-25-19	1.978	2.226	30.06	1098.8	34.61	18	0	30	72	60	1065.83	0.9152	357.82	0.1069	5141.77	1064316	NO
1_15_S3D	08-05-19	1.997	1.996	30.06	1031.4	48.08	26	10	20	72	54	1010.13	0.7050	437.16	0.1274	5331.70	1229271	NO
1_15_S4A	07-29-19	2.003	2.000	30.25	1138.3	58.35	24	25	15	72	60	981.45	0.8756	357.82	0.1060	5139.00	1196811	NO
1_15_W3D	07-25-19	1.962	1.966	30.13	980.5	31.01	22	15	10	72	59	1093.75	0.7626	339.97	0.0965	6072.13	1366997	NO

TABLE B.1: STATIC BENDING DATA, GREEN WOOD, .2"/MIN, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_15_W4A	07-22-19	1.992	1.981	30.00	1001.0	41.78	21	10	35	74	53	946.96	0.6534	319.21	0.0860	5061.43	1278725	NO
1_16_E3D	07-27-19	1.990	1.990	30.06	1237.7	60.60	28	25	15	72	60	1006.62	0.7285	324.55	0.1018	5366.75	1156997	NO
1_16_E4C	08-03-19	1.986	2.001	30.06	1168.3	51.04	24	15	20	70	59	1018.52	0.8983	310.21	0.1012	5422.13	1094831	NO
1_16_N2D	07-27-19	2.003	1.986	30.07	975.4	34.85	28	0	30	72	58	947.72	0.7713	429.69	0.1275	4997.41	1168045	NO
1_16_S2D	07-30-19	1.754	2.006	30.19	882.1	35.08	28	0	25	72	58	766.91	0.8404	344.09	0.1317	5221.04	1374388	NO
1_16_W3D	07-28-19	2.010	2.004	30.25	1141.5	61.04	32	25	25	72	58	986.02	0.7410	406.04	0.1244	5116.84	1144937	NO
1_16_W4C	07-31-19	2.021	2.032	30.15	1102.6	48.46	28	20	20	72	65	1063.23	0.7464	425.42	0.1082	5382.40	1353890	NO
1_17_N3D	08-05-19	2.001	1.997	30.12	1076.9	33.27	38	0	20	72	50	1207.43	0.6136	496.83	0.1116	6344.44	1577605	NO
1_19_N1C	07-29-19	1.952	2.102	30.03	1013.2	43.77	26	15	7	72	60	980.84	0.7413	408.78	0.1233	5145.27	1223606	NO
1_19_S4C	08-01-19	2.019	1.986	30.00	1615.2	121.54	24	90	20	70	66	1082.15	0.9179	357.67	0.0940	5616.18	1286498	NO
1_1_E3B	07-28-19	2.014	1.940	29.78	899.9	32.33	20	5	10	72	59	956.57	0.6988	312.65	0.1129	5107.43	980614	NO
1_1_E3D	08-01-19	2.002	2.006	30.00	1007.2	37.98	16	5	15	70	65	1027.83	0.6996	303.96	0.1059	5371.15	984421	NO
1_1_N2D	08-03-19	2.000	2.000	29.97	1012.8	32.95	24	0	15	72	51	984.95	0.7620	507.20	0.1700	5172.86	1011534	NO
1_1_S3H	07-30-19	1.987	2.001	30.13	1203.5	62.01	21	15	15	72	62	1010.90	0.9433	311.74	0.1117	5376.10	994369	NO
1_1_W3B	07-24-19	1.997	2.002	30.19	1015.4	29.88	18	0	15	74	56	1192.63	0.8793	437.16	0.1240	6276.09	1215916	NO
1_1_W4C	07-29-19	2.007	1.999	29.81	961.9	32.31	32	0	10	72	62	1026.31	0.7987	403.75	0.1175	5355.18	1213039	NO
1_20_E4A	08-05-19	1.999	1.999	30.09	871.2	35.52	18	5	15	72	55	843.81	0.7415	373.23	0.1230	4438.24	1087015	NO
1_20_N1C	07-23-19	1.982	1.974	30.12	960.5	35.24	22	0	20	72	65	814.36	0.4435	386.05	0.1421	4412.32	1003552	NO
1_20_N3K	08-04-19	1.767	1.986	30.19	864.0	32.98	22	0	20	71	58	669.56	0.9019	242.92	0.1328	4536.69	936242	NO
1_20_N3L	07-27-19	2.010	1.998	30.02	1011.8	34.17	14	0	30	72	58	1006.78	0.9952	288.24	0.0990	5240.22	993258	NO
1_20_N4K	07-30-19	2.000	2.005	29.99	1007.3	34.84	16	0	20	72	64	940.09	1.0179	345.76	0.1198	4924.94	1028253	NO
1_20_S3D	08-05-19	1.987	1.996	30.13	1153.2	61.85	22	20	20	72	49	1015.78	0.7079	437.01	0.1489	5415.60	1058862	NO
1_20_S3L	07-31-19	2.026	2.041	29.81	987.3	33.57	18	0	20	72	66	969.24	0.7822	437.32	0.1415	4860.86	1039375	NO
1_20_S4C	07-25-19	1.989	1.964	30.06	1216.3	36.15	16	40	35	72	60	891.72	0.6589	278.02	0.0999	4821.96	988668	NO
1_20_S4I	07-30-19	2.006	1.999	29.99	1042.6	33.61	19	0	35	72	59	1056.52	1.1405	297.85	0.1071	5518.32	956110	NO
1_20_W3H	07-28-19	2.006	2.005	30.03	921.0	35.46	21	5	45	71	60	761.41	0.5047	322.27	0.1044	3965.05	1091749	NO
1_21_E3D	08-01-19	2.020	2.022	29.88	985.4	42.28	24	7	10	70	68	977.63	0.6591	401.46	0.1040	4978.46	1301331	NO
1_21_E4C	08-03-19	2.001	1.996	29.95	1118.0	62.38	24	10	15	72	50	956.57	0.7390	415.34	0.1069	5028.84	1374265	NO
1_21_N1C	08-04-19	1.993	2.010	30.15	953.7	34.15	22	0	20	72	55	970.92	0.6723	443.57	0.1232	5109.47	1295387	NO
1_21_N3H	07-30-19	1.999	2.000	30.00	974.4	33.70	24	5	20	72	66	1041.57	0.7718	406.49	0.1073	5475.64	1361130	NO
1_21_N4A	07-29-19	2.010	2.009	30.63	970.4	39.51	23	7	15	72	60	919.34	0.7335	428.92	0.1203	4758.93	1266569	NO
1_21_N4G	07-31-19	2.036	2.037	29.84	1003.4	33.99	22	5	20	72	68	1088.26	0.7408	470.28	0.1189	5414.89	1304848	NO
1_21_S1A	08-05-19	2.003	1.995	30.00	969.7	37.03	28	0	15	72	55	981.14	0.8558	389.71	0.1152	5150.28	1195581	NO
1_21_S1C	08-03-19	1.999	1.990	30.00	965.4	35.19	25	0	25	72	52	959.17	0.7705	401.92	0.1091	5067.81	1305933	NO
1_21_S2B	07-30-19	1.998	2.008	30.00	963.4	33.38	30	0	5	72	61	962.22	0.6544	412.90	0.1053	5043.40	1404631	NO

TABLE B.1: STATIC BENDING DATA, GREEN WOOD, .2"/MIN, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_21_S2D	07-31-19	2.066	2.066	30.00	1054.5	33.23	22	0	15	72	66	1109.62	0.7792	455.02	0.1078	5286.73	1330341	NO
1_21_S3H	07-24-19	1.966	1.993	30.13	970.1	33.90	20	0	7	74	57	1018.68	0.7974	516.66	0.1591	5556.06	1243000	NO
1_21_W3B	07-30-19	2.002	2.001	29.99	933.1	32.79	26	0	10	72	66	1020.05	0.7195	485.99	0.1262	5343.81	1371585	NO
1_21_W4C	07-27-19	1.992	2.003	30.65	936.5	33.12	26	5	7	70	66	1002.66	0.6510	465.09	0.1127	5300.25	1463195	NO
1_22_S4G	07-22-19	1.978	1.976	30.00	990.2	30.67	24	0	25	73	53	1084.44	0.7891	569.00	0.1591	5893.47	1343097	NO
1_23_N3D	08-03-19	1.991	1.995	30.01	1069.6	36.51	28	0	15	72	53	1086.12	0.7582	438.54	0.1148	5770.28	1388000	NO
1_23_N4C	08-03-19	2.007	1.990	30.10	1141.3	38.93	30	20	15	72	56	1146.70	0.9548	372.92	0.1166	6010.43	1121730	NO
1_23_S4C	07-27-19	1.979	1.985	30.00	1073.4	34.33	26	0	5	72	58	1121.67	0.9047	501.10	0.1312	6062.04	1446829	NO
1_25_S3D	07-31-19	2.016	2.007	30.00	986.4	47.44	32	5	10	71	69	827.79	0.3781	419.46	0.1218	4263.79	1183952	NO
1_27_N3D	08-04-19	1.996	1.988	30.19	1030.7	36.47	28	0	10	72	58	1010.44	0.8832	397.03	0.1021	5360.14	1396726	NO
1_28_N3B	07-30-19	2.007	1.997	30.02	1020.0	32.13	23	0	7	71	68	1061.55	0.8703	411.22	0.1147	5544.64	1268431	NO
1_28_S3D	07-28-19	2.018	2.001	30.00	1081.7	34.36	28	0	15	71	62	1131.59	1.0981	455.32	0.1504	5834.52	1044056	NO
1_28_S3H	07-25-19	1.980	1.949	30.18	1015.1	35.21	30	5	20	72	60	961.00	0.8602	310.82	0.1024	5284.27	1094292	NO
1_28_S4G	08-01-19	1.753	2.007	29.96	893.9	33.86	32	0	25	70	64	794.68	0.9187	381.01	0.1920	5413.58	1051706	NO
1_29_N1C	07-27-19	1.978	1.989	30.05	1221.9	41.37	48	0	10	71	68	1097.87	0.9507	346.98	0.1210	5927.45	1045174	NO
1_29_S1C	08-05-19	2.003	2.001	29.94	1252.9	47.25	48	0	30	72	55	1120.76	0.9317	438.39	0.1403	5865.53	1113197	NO
1_2_N3D	08-03-19	1.997	1.999	29.91	1006.6	32.63	34	0	15	72	58	1034.70	0.6991	398.71	0.1180	5453.17	1216480	NO
1_2_S4C	07-22-19	1.972	1.994	30.00	1054.0	35.91	38	0	10	73	52	1208.50	0.9692	523.99	0.1392	6548.03	1398003	NO
1_2_S4D	07-28-19	2.001	2.004	27.88	1095.4	34.60	32	0	20	71	63	1230.93	0.8874	433.65	0.1143	6445.32	1355166	NO
1_4_E3C	08-04-19	1.999	2.004	30.14	1232.4	61.16	36	25	20	72	56	1089.48	0.7295	362.24	0.1063	5716.10	1211302	NO
1_4_E3D	08-04-19	2.007	2.003	30.14	1277.4	84.41	26	50	15	72	57	1066.28	0.8463	346.53	0.1015	5552.67	1184088	NO
1_4_N2C	08-03-19	1.900	2.001	29.94	918.1	33.15	28	0	20	72	51	962.98	0.8653	429.69	0.1607	5601.04	1107299	NO
1_4_N2D	08-03-19	1.999	1.992	29.90	979.0	31.51	28	0	10	72	57	1049.19	0.6663	412.90	0.1270	5537.90	1150936	NO
1_4_S2C	08-04-19	1.999	2.000	30.19	981.7	32.18	28	0	15	72	65	1071.01	0.8271	495.15	0.1539	5630.46	1148262	NO
1_4_S2D	07-22-19	1.997	1.965	30.12	958.7	31.82	32	0	15	73	52	884.40	0.9423	343.48	0.1065	4741.70	1119983	NO
1_4_W3D	07-31-19	2.053	2.048	30.00	1302.9	69.83	26	65	25	72	68	1033.78	0.6477	450.59	0.1116	5031.83	1298337	NO
1_5_N1C	07-27-19	1.985	2.000	30.00	951.7	33.93	21	0	15	72	58	931.70	0.8342	430.30	0.1337	4967.41	1192969	NO
1_5_N1I	08-03-19	2.001	1.993	29.97	976.2	34.64	20	0	20	70	60	1010.28	0.9005	411.99	0.1252	5319.20	1178016	NO
1_5_N4F	07-27-19	2.001	1.995	30.04	1100.9	51.23	20	15	15	72	62	890.35	0.6748	463.56	0.1497	4683.04	1045344	NO
1_5_S1C	07-22-19	1.988	1.974	30.00	886.1	31.26	21	5	30	74	52	807.50	0.6813	391.08	0.1362	4348.75	1028804	NO
1_5_S1G	07-31-19	2.009	2.017	30.00	988.7	33.09	16	0	30	70	70	966.34	0.6688	353.70	0.1024	4987.33	1201610	NO
1_5_S2J	08-04-19	1.878	2.002	30.00	987.5	34.88	16	0	15	72	56	861.82	0.9429	416.72	0.1655	5128.19	1080296	NO
1_5_W3J	08-03-19	2.000	2.002	30.09	970.4	39.49	16	5	20	72	55	890.20	0.7925	406.65	0.1246	4670.54	1155184	NO
1_5_W4C	07-23-19	1.973	1.976	30.00	906.6	35.11	22	0	25	70	65	831.76	0.6596	362.85	0.1162	4543.18	1153633	NO
1_6_N3D	07-31-19	2.007	2.025	30.00	995.6	32.81	18	0	20	70	70	1016.54	0.8357	425.11	0.1401	5236.12	1062582	NO

TABLE B.1: STATIC BENDING DATA, GREEN WOOD, .2"/MIN, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_6_S3D	08-04-19	1.992	1.996	30.19	993.9	32.55	26	0	25	71	57	870.36	0.7430	395.36	0.1443	4617.05	992436	NO
1_7_N1C	08-01-19	1.995	2.003	30.00	1126.8	38.81	22	0	30	70	65	1252.59	0.9742	411.53	0.1420	6601.58	1040804	NO
1_7_N2D	08-05-19	1.996	2.003	30.05	1094.5	33.31	24	0	25	72	50	990.91	1.1690	267.64	0.1075	5217.17	882705	NO
1_7_W4C	08-05-19	1.996	1.997	30.09	1066.1	39.51	40	5	15	72	56	998.23	0.8891	305.33	0.1030	5271.52	1052570	NO
1_9_E3D	08-05-19	1.739	1.995	30.13	921.6	53.17	22	10	20	72	49	737.15	0.8199	266.27	0.1379	5133.57	1054583	NO
1_9_N2D	08-05-19	1.998	1.991	30.00	898.0	31.36	24	0	10	72	50	950.32	0.8473	391.24	0.1345	5023.55	1046829	NO
1_9_S2D	08-05-19	2.000	2.001	30.00	903.1	31.09	19	0	20	72	50	892.03	0.6884	442.20	0.1679	4682.48	933128	NO
1_1_S2H	07-27-19	1.988	1.996	30.06	1049.6	33.01	16	0	20	70	69	967.25	0.6677	292.36	0.1076	5151.72	981139	YES
1_1_S4A	07-27-19	2.018	1.951	29.95	1207.1	77.68	22	35	40	72	64	928.50	0.8553	349.88	0.1299	4910.04	941252	YES
1_1_S4C	07-29-19	1.794	1.794	30.13	818.9	45.56	20	0	15	72	60	687.56	0.7541	296.94	0.1568	5003.21	1042474	YES
1_1_S4G	07-30-19	2.008	2.001	29.97	1114.6	50.40	16	20	20	72	62	968.17	0.8027	293.58	0.1071	5041.75	956716	YES
1_20_E3D	08-04-19	2.007	2.007	30.13	947.1	36.52	18	0	15	72	55	791.47	0.8110	286.56	0.0994	4113.38	994784	YES
1_20_N2D	07-31-19	1.742	2.003	30.00	795.5	58.35	22	0	10	72	65	524.44	0.4968	278.63	0.1604	3625.16	936677	YES
1_20_N4A	08-05-19	2.001	1.999	29.94	997.9	55.71	20	0	25	72	57	857.54	0.7127	358.73	0.1182	4501.46	1069228	YES
1_20_N4L	08-04-19	1.891	1.968	30.05	878.4	33.00	16	0	10	72	58	791.63	0.5771	331.57	0.1323	4726.25	1060344	YES
1_20_S1C	08-04-19	2.005	2.001	30.00	931.8	35.19	18	0	25	72	56	754.55	0.6407	308.23	0.1134	3941.08	955693	YES
1_20_S3J	07-31-19	2.021	2.022	30.05	1002.6	36.88	20	5	20	72	68	940.09	0.7276	341.49	0.1189	4782.58	976847	YES
1_20_S4A	08-05-19	1.998	1.999	30.01	906.8	31.98	22	0	15	72	56	838.62	0.7031	371.86	0.1223	4415.37	1082479	YES
1_20_W4C	08-03-19	2.007	2.005	30.13	967.8	35.27	20	0	15	72	52	851.59	0.5701	291.60	0.1043	4430.24	984276	YES
1_25_N3D	07-27-19	1.988	1.991	30.00	962.1	32.21	30	0	25	72	58	813.45	0.8841	348.66	0.1346	4343.39	943170	YES
1_29_E4C	07-24-19	1.708	1.730	30.13	755.3	29.54	28	0	20	74	58	665.13	0.9191	225.68	0.1364	5537.19	1085905	YES
1_29_W4C	08-04-19	1.944	1.947	30.13	997.3	33.38	24	5	20	72	57	988.01	0.9630	423.28	0.1795	5641.65	938538	YES
1_5_E3D	07-22-19	1.970	1.967	30.00	1127.0	59.34	20	0	20	76	51	755.77	0.5623	310.82	0.1152	4159.64	1016931	YES
1_5_W3D	07-24-19	1.966	1.941	30.10	1011.9	56.66	20	20	35	74	58	796.66	0.7431	315.70	0.1111	4461.55	1106325	YES
1_7_E4C	08-04-19	2.008	1.974	30.13	1101.1	30.14	28	0	35	72	56	915.53	1.3253	254.52	0.1319	4832.83	675796	YES
1_7_W3D	07-30-19	1.747	1.997	30.31	986.6	34.56	38	10	5	72	59	693.82	0.7371	253.91	0.1413	4782.84	970548	YES

TABLE B.2: STATIC BENDING DATA, GREEN WOOD, .1"/MIN

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_10_E3B	02-12-19	2.004	2.020	30.13	1570.7	88.11	30	60	15	75	24	1267.70	0.8157	279.39	0.0863	6565.59	1139193	NO
1_10_N2C	02-12-19	2.016	2.021	30.38	1065.2	33.37	24	0	10	75	24	1031.19	0.7727	286.10	0.0796	5274.67	1287440	NO
1_10_N2D	02-25-19	2.016	2.008	30.06	1137.8	31.78	28	0	15	75	20	1069.03	0.6424	234.83	0.0655	5503.64	1273609	NO
1_10_N3H	02-24-19	2.016	2.002	29.88	1111.2	34.08	24	10	10	72	28	1139.53	0.7274	258.79	0.0697	5884.15	1327799	NO
1_10_S3H	02-22-19	2.001	2.009	30.13	1078.5	34.33	32	0	10	75	30	1070.86	1.0124	300.75	0.0943	5593.24	1162274	NO
1_10_S4G	02-22-19	2.013	2.014	30.19	1139.5	47.36	24	20	15	75	30	1131.59	0.7808	398.86	0.1086	5825.69	1275029	NO
1_10_W3B	02-23-19	2.010	2.022	30.13	1268.7	59.69	30	10	10	75	30	1093.45	0.7779	350.04	0.0915	5623.78	1355220	NO
1_11_N3J	02-23-19	2.002	1.997	30.00	983.1	34.18	24	5	10	75	30	890.50	0.8488	293.12	0.0946	4674.48	1132432	NO
1_11_S4I	02-15-19	2.008	2.011	30.10	1036.5	33.12	20	0	10	75	24	1021.42	0.7428	338.75	0.0995	5292.62	1200955	NO
1_12_N4A	02-23-19	1.910	1.991	30.00	1043.3	31.7	38	0	10	75	30	1025.39	0.7556	283.20	0.0876	5931.38	950913.9	NO
1_13_N4C	02-25-19	2.017	2.001	30.06	1098.9	32.18	24	0	15	75	20	1296.23	0.9188	382.39	0.1090	6690.04	1235595	NO
1_14_S4C	02-10-19	2.016	2.013	30.83	1058.8	34.99	22	0	15	75	24	1037.29	0.8630	431.06	0.1444	5326.97	1039365	NO
1_15_E4C	02-16-19	2.018	2.016	30.03	988.9	33.8	24	0	10	75	24	992.43	0.8513	389.56	0.1148	5078.93	1188223	NO
1_15_S1C	02-24-19	2.008	2.012	30.06	1225.8	33.69	26	0	15	72	28	1013.64	0.8746	424.19	0.1275	5249.68	1162748	NO
1_15_S2B	02-22-19	2.012	2.007	30.13	1005.7	35.03	20	0	7	75	30	984.19	0.7121	277.25	0.0826	5089.57	1200312	NO
1_17_S4C	02-16-19	2.014	2.005	30.13	1094.0	33.99	38	0	10	75	24	1170.65	0.8398	355.68	0.0833	6047.83	1515348	NO
1_19_E3D	02-23-19	2.015	1.870	30.25	1298.2	65.67	24	0	15	75	30	1035.61	0.9316	264.59	0.0956	5730.74	1047749	NO
1_19_N2D	02-26-19	2.000	1.977	30.00	1001.5	35.71	24	0	10	75	20	1080.02	0.8352	524.60	0.1473	5738.10	1288480	NO
1_19_S2D	02-22-19	2.002	2.007	29.88	997.5	34.77	28	0	10	75	30	1014.10	0.7892	425.26	0.1303	5296.75	1162617	NO
1_19_S4C	02-16-19	2.015	2.025	30.13	1113.9	54.17	22	25	10	75	28	1036.68	0.7160	281.98	0.0763	5297.55	1300601	NO
1_19_W3D	02-10-19	2.013	2.017	30.81	1488.8	109.11	18	70	15	75	24	1014.25	0.8713	389.25	0.1154	5213.83	1191787	NO
1_1_N1G	02-25-19	2.013	2.009	30.25	1047.8	32.42	28	0	15	75	20	956.42	0.7527	210.57	0.0700	4936.12	1087951	NO
1_1_N2B	02-16-19	2.014	2.018	30.19	973.5	32.67	26	0	10	75	28	909.58	0.5313	426.48	0.1376	4668.78	1082982	NO
1_1_N2H	02-22-19	1.994	2.005	30.13	1067.9	35.07	28	0	15	75	30	920.56	0.8065	206.76	0.0755	4851.69	1027911	NO
1_1_N3D	02-24-19	2.007	2.003	30.00	976.3	32.04	20	0	15	72	28	1080.78	0.7210	361.18	0.0992	5628.15	1233764	NO
1_1_S1A	02-15-19	2.019	2.007	30.25	1042.1	30.88	28	0	15	75	24	948.18	0.7594	824.74	0.2503	4869.40	1148380	NO
1_1_S1B	02-16-19	2.018	2.008	29.56	973.0	31.33	26	0	15	75	24	1006.78	0.8029	797.58	0.2280	5172.86	1227806	NO
1_1_W3H	02-23-19	2.007	2.009	30.19	1012.3	32.67	22	0	10	75	30	953.98	0.7493	222.17	0.0799	4953.01	1020801	NO
1_1_W4G	02-23-19	2.010	2.010	32.38	1395.9	77.23	18	60	15	75	30	899.66	0.7525	223.54	0.0800	4654.72	1007525	NO
1_21_N2D	02-25-19	2.009	1.993	30.13	980.1	35	24	0	10	75	20	1021.27	0.7132	334.93	0.0870	5334.31	1382391	NO
1_21_N4A	02-22-19	1.914	2.003	30.25	1027.0	54.42	22	5	10	75	30	812.53	0.6862	374.60	0.0973	4652.42	1183348	NO
1_21_N4C	02-10-19	2.000	2.006	30.81	1263.9	70.34	28	50	10	75	24	917.97	0.6970	352.94	0.1021	4806.64	1254582	NO
1_21_S1A	02-22-19	1.996	1.974	30.06	993.2	36.18	24	0	10	75	30	949.10	0.7498	728.45	0.2025	5070.45	1305811	NO
1_21_S4C	02-26-19	1.999	2.000	30.13	975.9	32.85	20	5	10	75	20	951.69	0.5187	434.27	0.0748	5003.16	1273471	NO
1_21_W3D	02-24-19	2.000	2.010	29.75	1074.3	53.01	24	5	10	72	28	1026.31	0.6840	531.16	0.1425	5363.22	1322156	NO

TABLE B.2: STATIC BENDING DATA, GREEN WOOD, .1"/MIN, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_22_S3H	02-26-19	2.006	2.015	29.13	1010.2	32.75	22	0	10	75	20	1132.05	0.8265	446.93	0.1223	5865.88	1296477	NO
1_27_N4C	02-16-19	1.999	2.007	30.13	1046.8	36.63	28	0	10	75	28	1000.67	0.8900	375.37	0.1113	5242.31	1220637	NO
1_28_N3D	02-16-19	2.015	2.009	30.13	1033.2	32.23	28	0	10	75	24	995.94	0.6344	445.86	0.1252	5129.89	1241724	NO
1_29_S2D	02-22-19	2.003	1.999	30.19	1213.7	43.32	38	0	15	75	30	1016.54	0.8713	397.49	0.1441	5325.43	987320.5	NO
1_29_S4C	02-15-19	1.963	1.929	30.19	1014.6	31.17	32	0	15	75	24	928.96	0.7645	391.08	0.1644	5250.81	932450.3	NO
1_2_S3D	02-24-19	2.005	2.002	29.13	991.0	38.16	44	5	10	72	28	936.58	0.4206	262.15	0.0627	4889.43	1354801	NO
1_4_W3D	02-10-19	1.967	2.000	30.13	1082.0	53.47	23	5	10	75	24	916.44	0.4909	262.76	0.0765	4975.89	1314091	NO
1_5_E3J	02-12-19	2.022	2.009	30.25	1202.0	63.53	16	30	15	75	24	918.27	0.6360	212.25	0.0651	4697.15	1164250	NO
1_5_N2D	02-10-19	2.017	2.013	30.81	996.7	32.11	22	0	15	75	24	885.93	0.6737	490.88	0.1645	4545.13	1067435	NO
1_5_N3D	02-16-19	1.989	1.978	30.19	1285.0	94.22	20	50	15	75	24	853.88	0.6766	426.64	0.1338	4584.65	1174536	NO
1_5_W3H	02-12-19	2.015	2.017	30.25	963.7	36.3	20	5	10	75	24	898.74	0.6261	232.54	0.0668	4610.88	1257091	NO
1_5_W4C	02-23-19	1.993	2.012	30.13	945.5	34.4	22	0	10	75	30	861.05	0.6815	368.35	0.1028	4526.81	1239983	NO
1_5_W4I	02-24-19	1.991	2.001	30.25	1149.9	71.21	24	50	10	72	30	888.52	0.6406	252.38	0.0777	4706.32	1209894	NO
1_6_S3D	02-10-19	1.976	2.004	31.13	1044.4	32.02	19	0	15	75	24	955.81	0.5681	410.31	0.1554	5132.21	981326.7	NO
1_9_E4C	02-12-19	2.017	2.004	30.13	1113.3	61.03	22	35	15	75	24	857.54	0.8609	260.01	0.0960	4419.28	954452.5	NO
1_9_N1C	02-24-19	2.014	2.008	29.84	899.8	33.83	18	0	10	72	28	940.09	0.8263	316.01	0.0946	4849.46	1076186	NO
1_9_W3D	02-24-19	2.000	2.004	30.00	962.3	38.1	24	5	7	72	28	888.98	0.7830	205.38	0.0648	4659.48	1042517	NO
1_10_S1A	02-22-19	2.004	1.998	30.25	1045.5	37.56	18	0	15	75	30	882.26	0.6963	458.68	0.1726	4619.68	942089	YES
1_12_S3H	02-24-19	2.017	2.018	30.19	1052.5	34.51	24	0	10	72	28	927.43	0.5936	323.49	0.1008	4746.27	1123536	YES
1_12_S4G	02-25-19	1.997	2.009	30.13	1064.1	33.63	22	0	15	75	20	889.28	0.7353	308.08	0.1005	4663.46	1113206	YES
1_16_N1C	02-24-19	2.008	2.010	30.13	993.0	32.89	22	0	10	72	28	888.82	0.5111	264.59	0.0764	4607.84	1195217	YES
1_16_S1C	02-24-19	2.008	2.014	30.19	1058.2	34.77	30	0	10	72	28	893.71	0.5086	226.90	0.0673	4623.95	1060886	YES
1_1_E3D	02-22-19	2.001	1.994	30.25	1349.5	92.94	24	50	10	75	30	888.82	0.7132	272.37	0.0932	4677.36	1079486	YES
1_1_N1A	02-25-19	1.992	2.014	28.83	966.9	36.81	16	0	10	75	20	855.87	1.1422	347.14	0.1447	4499.58	866422.1	YES
1_20_S3D	02-25-19	2.020	2.009	30.00	1069.0	52.54	18	10	15	75	20	790.86	0.6912	246.89	0.0762	4053.43	1148588	YES
1_21_S2B	02-22-19	1.929	1.996	29.94	944.6	34.62	16	0	20	75	30	889.74	0.8409	133.06	0.0075	5033.18	8923910	YES
1_28_N4C	02-24-19	1.995	2.004	29.84	939.5	34.68	24	0	15	72	30	736.39	0.4243	267.33	0.0843	3879.08	1178849	YES
1_5_E3D	02-22-19	2.012	1.996	30.13	1035.8	39.8	22	25	15	75	30	885.93	0.6312	208.59	0.0757	4606.65	1008754	YES
1_5_N2J	02-10-19	2.012	2.023	31.13	1014.8	33.53	22	0	15	75	24	847.17	0.6742	245.06	0.0905	4346.32	957554.1	YES
1_5_S2H	02-26-19	2.007	2.013	30.13	1014.6	35.83	16	5	15	75	20	868.99	0.6486	179.29	0.0591	4502.77	1087996	YES
1_9_W4C	02-15-19	2.012	2.007	30.13	911.5	34.42	20	0	10	75	24	759.58	0.3339	218.35	0.0575	3928.04	1167977	YES

TABLE B.3: STATIC BENDING DATA, SEASONED WOOD

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_10_N3C	03-17-19	1.979	1.985	30.06	871.7	12.97	22	75	10	72	20	1718.75	0.7799	639.95	0.1461	9288.9	1609810	NO
1_10_N3G	03-12-19	2.002	2.003	30.00	1000.3	14.60	22	0	10	72	15	1729.13	0.5850	635.53	0.1552	9049.4	1445962	NO
1_10_N4D	03-05-19	2.002	2.007	30.00	882.0	16.50	24	10	10	72	20	1541.75	0.8775	660.55	0.1625	8052.7	1421115	NO
1_10_N4H	03-16-19	1.965	1.983	29.94	920.2	12.92	20	15	10	72	20	1858.67	0.6652	721.74	0.1705	10199.1	1598953	NO
1_10_S2A	03-04-19	1.999	1.992	30.13	891.2	15.34	23	0	10	72	20	1420.59	0.8294	999.30	0.3419	7498.2	1049039	NO
1_10_S4H	03-02-19	2.013	1.995	30.06	982.9	14.17	26	0	10	72	20	1798.25	0.7435	499.27	0.1326	9346.0	1316327	NO
1_10_W4B	03-08-19	1.994	1.991	30.00	965.1	15.94	30	35	15	72	20	1718.90	0.8240	585.78	0.1319	9122.9	1601226	NO
1_10_W4D	03-08-19	2.007	2.009	30.06	959.9	16.77	24	25	15	72	20	1638.03	0.7792	583.95	0.1277	8504.6	1613056	NO
1_11_E4D	03-22-19	1.991	1.932	30.06	881.6	12.63	24	20	15	72	20	1681.06	0.6213	969.24	0.2363	9222.3	1515401	NO
1_11_N3C	03-11-19	2.122	2.077	30.00	970.7	15.08	32	15	10	72	20	1936.19	0.9862	498.05	0.1046	8698.1	1375817	NO
1_11_S2C	03-22-19	1.990	2.002	30.06	900.7	12.86	28	0	10	72	20	1614.84	0.5633	498.05	0.1224	8557.8	1473723	NO
1_11_W3C	03-17-19	2.001	1.989	30.13	873.5	13.14	24	10	10	72	20	1610.87	0.5601	1507.72	0.3427	8498.4	1565090	NO
1_12_N3I	03-12-19	1.984	1.998	30.00	917.3	16.04	20	0	15	72	20	1494.45	0.6185	639.34	0.1611	7983.7	1448047	NO
1_12_N3K	03-12-19	2.000	1.983	30.00	907.4	14.54	24	0	15	72	20	1569.67	0.5534	981.60	0.2659	8314.4	1329524	NO
1_12_N4B	03-16-19	1.993	1.981	30.00	1024.1	13.23	22	0	15	72	20	1564.79	0.4324	432.43	0.0951	8355.3	1648079	NO
1_12_N4H	03-09-19	2.009	2.000	30.06	956.4	14.26	26	25	15	72	20	1681.67	0.5486	688.48	0.1610	8753.0	1499280	NO
1_12_N4L	03-16-19	1.978	1.995	30.00	940.6	12.76	18	0	15	72	20	1649.93	0.5505	986.02	0.2546	8881.3	1441045	NO
1_12_S3G	03-16-19	1.985	1.980	30.06	919.6	12.82	22	0	15	72	20	1789.55	0.6283	986.18	0.2343	9637.5	1533935	NO
1_12_S3I	03-05-19	1.998	1.998	30.00	923.3	16.21	26	0	10	72	20	1532.14	0.7200	499.27	0.1312	8070.8	1372103	NO
1_12_S4D	03-08-19	1.998	2.001	30.00	1005.1	14.69	36	0	15	72	20	1852.88	0.5577	750.43	0.1608	9745.7	1657099	NO
1_12_S4J	03-05-19	2.002	2.008	30.00	931.5	15.80	18	0	10	72	20	1548.00	0.5553	279.69	0.0683	8081.4	1480958	NO
1_13_N3C	03-22-19	1.997	1.999	30.00	924.7	14.05	22	0	10	72	20	1727.75	0.9013	945.74	0.2557	9105.8	1311979	NO
1_13_S3A	03-03-19	2.003	1.990	29.94	959.8	14.87	28	0	15	72	20	1847.99	0.8843	717.01	0.1956	9725.0	1296979	NO
1_14_S3C	03-11-19	1.988	1.986	30.06	864.4	15.61	32	0	15	72	20	1410.68	0.4775	342.87	0.0845	7551.3	1506865	NO
1_15_E3B	03-02-19	2.007	2.006	29.75	907.7	15.56	25	30	15	72	20	1446.69	0.5313	450.13	0.1062	7522.3	1503189	NO
1_15_E3D	03-05-19	1.988	1.990	30.06	914.2	14.17	24	0	15	72	20	1614.23	0.5606	749.21	0.1731	8623.5	1572702	NO
1_15_N1D	03-11-19	2.079	2.059	30.00	1008.3	16.11	28	0	20	72	20	1554.72	0.5530	491.33	0.1169	7339.9	1307990	NO
1_15_N2C	03-22-19	2.019	2.009	30.00	954.0	13.53	30	0	15	72	20	1497.65	0.4708	760.65	0.1919	7683.6	1352117	NO
1_15_N3A	03-09-19	2.008	1.995	30.13	854.8	16.39	22	10	10	72	20	1495.21	0.8581	377.50	0.1023	7809.7	1329826	NO
1_15_N4B	03-16-19	1.992	1.989	30.00	884.8	13.68	28	25	15	72	20	1571.96	0.6635	577.85	0.1653	8368.2	1266061	NO
1_15_S2A	03-02-19	2.004	2.007	29.81	884.7	14.80	22	0	15	72	20	1535.80	0.7913	494.38	0.1288	8005.6	1353204	NO
1_15_S3A	03-03-19	2.002	2.004	60.06	868.0	15.15	28	5	10	72	20	1601.56	0.7547	791.02	0.1948	8377.7	1433777	NO
1_15_S3C	03-16-19	1.985	1.978	29.94	876.3	13.55	30	75	10	72	20	1850.43	0.7876	650.63	0.1486	9975.4	1602214	NO
1_15_S4B	03-08-19	1.996	1.998	30.06	882.3	15.13	28	25	15	72	20	1508.33	0.8772	417.18	0.1032	7961.3	1464258	NO
1_15_S4D	03-18-19	1.995	1.984	30.00	883.2	13.33	22	5	10	72	20	1604.46	0.8040	513.00	0.1204	8537.0	1529105	NO

TABLE B.3: STATIC BENDING DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_15_W3A	03-04-19	2.003	2.003	30.00	921.0	15.76	22	0	15	72	20	1634.98	0.7585	450.59	0.0959	8548.2	1694140	NO
1_15_W3C	03-02-19	2.006	2.004	30.06	962.4	15.92	22	0	15	72	20	1674.35	0.6058	750.89	0.1608	8723.5	1650535	NO
1_16_E3C	03-15-19	1.965	1.980	30.00	897.7	13.23	20	30	15	72	20	1592.10	0.4935	647.13	0.1472	8749.5	1650911	NO
1_16_E4D	03-15-19	1.958	1.979	30.13	909.9	13.28	20	15	15	75	20	1574.86	0.4867	286.41	0.0633	8721.2	1778869	NO
1_16_N1D	03-02-19	2.006	2.009	30.19	901.4	15.78	22	0	10	72	20	1648.41	0.9102	614.93	0.1430	8567.0	1503950	NO
1_16_N2C	03-08-19	2.003	2.000	30.00	913.4	15.19	34	0	10	72	20	1597.60	0.6325	832.82	0.2025	8365.3	1474307	NO
1_16_S1D	03-15-19	1.986	1.975	30.06	876.4	12.94	30	0	10	72	20	1559.45	0.4715	415.50	0.0902	8411.0	1682852	NO
1_16_S2C	03-15-19	1.976	1.992	30.00	890.7	13.00	20	0	10	72	20	1739.04	0.8844	615.23	0.1528	9394.0	1478103	NO
1_16_W3C	03-08-19	2.005	1.996	30.06	890.9	15.67	22	50	10	72	20	1535.19	0.7480	489.65	0.1158	8038.5	1490123	NO
1_16_W4D	03-15-19	1.994	1.979	30.00	872.1	13.11	26	30	10	72	20	1705.78	0.6199	560.76	0.1316	9108.2	1551158	NO
1_17_N3C	03-18-19	2.004	1.995	30.00	991.9	12.63	35	0	10	72	20	2164.61	0.7685	664.22	0.1253	11351.3	1857849	NO
1_17_N4D	03-17-19	1.998	1.985	30.00	992.1	12.94	26	0	10	72	20	2008.21	0.7070	638.43	0.1223	10647.9	1876145	NO
1_17_S3C	03-09-19	1.998	2.001	30.06	1016.6	14.68	40	0	15	72	20	2008.21	0.9142	1159.97	0.2450	10562.7	1670418	NO
1_17_S4D	03-04-19	1.977	2.001	30.00	993.5	14.17	26	0	15	72	20	1936.32	0.8462	453.19	0.0874	10412.9	1913049	NO
1_19_S3C	03-11-19	2.130	2.140	30.06	1007.2	15.83	30	0	15	72	20	1784.06	0.8183	817.41	0.1706	7720.4	1309160	NO
1_1_E4B	03-08-19	2.011	1.992	30.00	841.5	16.69	20	0	10	72	20	1354.52	0.6243	582.58	0.1688	7064.4	1219761	NO
1_1_N1B	03-15-19	1.976	1.986	30.00	820.1	13.36	18	0	10	72	20	1528.78	0.6284	424.35	0.1191	8283.2	1332666	NO
1_1_N1D	03-17-19	1.992	1.992	30.06	873.5	13.03	28	0	10	72	20	1605.84	0.6230	648.19	0.1691	8535.7	1372155	NO
1_1_N2G	03-15-19	1.971	1.984	29.94	944.4	13.15	28	0	15	72	20	1404.72	0.3922	653.08	0.1588	7657.4	1540381	NO
1_1_S1D	03-16-19	1.987	1.987	29.94	899.2	13.84	22	0	15	72	20	1628.11	0.7313	798.65	0.2051	8719.6	1412440	NO
1_1_S3C	03-18-19	1.997	1.994	30.00	859.8	12.78	24	40	10	72	20	1680.15	0.8141	575.10	0.1580	8877.1	1302657	NO
1_1_W3G	03-18-19	1.991	1.992	30.00	863.2	12.72	18	20	15	72	20	1509.09	0.4842	369.26	0.0950	8029.5	1404410	NO
1_1_W4A	03-04-19	1.992	1.999	30.00	937.9	14.48	40	5	15	72	20	1703.95	0.6739	452.42	0.1073	9025.5	1521458	NO
1_1_W4B	03-08-19	1.987	2.002	30.06	888.1	14.19	30	0	10	72	20	1639.25	0.5729	887.30	0.2064	8713.5	1546107	NO
1_1_W4D	03-15-19	1.972	1.985	30.00	824.2	13.02	28	0	10	72	20	1455.08	0.4576	624.54	0.1566	7919.8	1494859	NO
1_1_W5A	03-08-19	2.006	1.998	30.06	985.5	15.45	18	0	25	72	20	1682.43	0.7689	822.30	0.2208	8791.9	1303163	NO
1_20_N4L	03-11-19	2.010	2.022	30.00	933.8	15.71	17	0	15	72	20	1512.76	0.6346	521.70	0.1386	7780.4	1308599	NO
1_20_S3I	03-17-19	1.998	2.003	30.00	863.6	13.77	18	0	10	72	20	1654.36	0.6159	515.14	0.1331	8692.8	1381210	NO
1_20_S3K	03-12-19	1.995	1.984	30.06	863.3	17.12	26	10	15	72	20	1359.25	0.7128	568.85	0.1675	7232.3	1224480	NO
1_21_E3C	03-18-19	1.985	2.007	30.00	857.6	12.61	24	35	10	72	20	1605.38	0.6881	980.07	0.2205	8529.3	1590119	NO
1_21_E4B	03-11-19	2.007	2.001	30.06	865.9	15.19	32	35	10	72	20	1536.10	0.7761	1082.15	0.2692	8007.2	1417113	NO
1_21_E4D	03-17-19	1.985	1.987	30.00	849.0	13.79	28	50	10	72	20	1603.24	0.7674	1544.95	0.3629	8603.7	1552051	NO
1_21_N1C	03-18-19	2.008	1.983	30.00	873.1	13.25	26	0	10	72	20	1796.88	0.8288	647.74	0.1532	9442.2	1488980	NO
1_21_N1D	03-12-19	2.157	2.157	30.00	1023.4	15.34	25	0	10	72	20	2077.94	0.6077	405.88	0.0679	8699.4	1612704	NO
1_21_S1D	03-03-19	1.996	1.986	30.00	908.5	15.95	32	0	10	72	20	1739.66	0.8935	649.26	0.1425	9237.8	1643779	NO

TABLE B.3: STATIC BENDING DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_21_S4H	03-04-19	1.996	1.981	30.00	882.9	15.69	28	0	10	72	20	1540.38	0.5652	546.42	0.1294	8200.2	1542502	NO
1_21_W3C	03-22-19	2.075	2.046	30.13	955.7	13.10	24	0	10	72	20	2021.18	0.8503	669.56	0.1238	9639.8	1674317	NO
1_22_S3G	03-11-19	2.000	1.986	30.00	950.5	14.97	24	0	15	72	20	1768.34	0.6790	1656.65	0.3688	9352.6	1604205	NO
1_23_N3C	03-16-19	1.968	1.977	30.00	939.1	13.02	32	15	10	72	20	1898.80	0.7092	603.94	0.1267	10419.0	1811222	NO
1_23_N4D	03-12-19	1.979	1.999	30.00	969.1	16.06	34	0	10	72	20	1704.10	0.6114	608.06	0.1319	9145.3	1699175	NO
1_23_S4D	03-22-19	1.996	1.980	30.06	953.9	13.23	34	0	15	72	20	2109.68	0.9805	1190.80	0.2441	11236.6	1733685	NO
1_27_N3C	03-22-19	1.988	1.969	30.06	915.9	13.86	30	0	10	72	20	1818.39	0.8917	811.77	0.1789	9817.8	1659403	NO
1_28_N3C	03-04-19	2.000	2.000	30.00	917.6	12.83	38	0	15	72	20	1689.61	0.7366	706.02	0.1617	8873.6	1486939	NO
1_28_N4B	03-11-19	2.015	1.763	30.00	837.2	14.86	30	0	10	72	20	1580.96	0.9350	474.55	0.1337	9279.5	1403176	NO
1_28_S3G	03-03-19	2.008	2.009	30.00	916.3	15.39	30	0	10	72	20	1623.38	0.8143	522.31	0.1415	8420.1	1293374	NO
1_29_E3C	03-15-19	1.990	1.971	29.81	895.5	12.99	24	15	20	72	20	1591.64	0.6697	926.06	0.2868	8567.6	1185238	NO
1_29_N2C	03-11-19	2.003	2.022	30.00	1040.6	15.12	28	0	20	72	20	1642.15	0.6116	524.14	0.1427	8505.0	1287455	NO
1_29_S2C	03-04-19	1.953	1.997	30.06	1002.1	13.08	40	0	15	72	20	1800.08	1.0668	439.15	0.1354	9929.2	1221007	NO
1_2_N4D	03-22-19	2.026	2.011	30.13	937.5	13.70	40	0	10	72	20	1601.41	0.3866	531.16	0.1094	8151.1	1666731	NO
1_30_S4D	03-16-19	1.959	1.977	30.00	992.5	14.02	24	0	15	72	20	1866.15	0.6002	874.79	0.1974	10334.2	1685153	NO
1_4_N1D	03-17-19	2.004	2.003	30.00	889.6	13.85	30	0	10	72	20	1479.80	0.4051	1175.39	0.2815	7729.1	1469840	NO
1_4_S1D	03-02-19	2.008	2.010	30.25	947.2	15.02	24	0	10	72	20	1755.37	0.8789	765.69	0.2027	9100.2	1312215	NO
1_4_W3D	03-11-19	1.993	2.067	30.00	886.7	14.32	24	10	15	72	20	1705.93	0.6770	515.90	0.1153	8729.9	1569020	NO
1_5_E3C	03-17-19	1.999	1.998	30.00	836.3	13.42	22	0	15	72	20	1488.34	0.4906	363.62	0.0917	7832.2	1464529	NO
1_5_E3I	03-12-19	2.151	1.992	30.00	965.7	16.37	20	10	15	72	20	1618.65	0.4775	455.78	0.0925	7378.8	1456171	NO
1_5_E4D	03-12-19	1.992	1.994	30.00	848.0	15.93	26	40	10	72	20	1388.25	0.8514	402.68	0.1189	7371.7	1243332	NO
1_5_N1D	03-11-19	2.048	2.063	30.00	924.0	15.56	20	0	10	72	20	1658.63	0.8273	1014.86	0.2332	8053.7	1377473	NO
1_5_N1J	03-15-19	1.990	1.971	30.00	879.4	13.83	18	0	10	72	20	1698.15	0.5944	812.68	0.2020	9140.9	1451581	NO
1_5_S2G	03-09-19	1.997	2.005	30.00	936.6	14.65	24	0	10	72	20	1575.93	0.7482	560.91	0.1441	8280.8	1393454	NO
1_5_S2I	03-15-19	1.997	1.988	30.00	900.3	13.93	22	0	10	72	20	1495.51	0.9025	530.70	0.1650	7925.4	1155526	NO
1_5_W3C	03-18-19	1.993	1.987	30.00	858.2	13.18	24	20	10	72	20	1572.42	0.7107	1519.93	0.3837	8370.7	1419503	NO
1_5_W4J	03-16-19	1.987	1.994	30.00	838.7	13.83	24	15	15	72	20	1601.72	0.8543	850.52	0.2178	8548.1	1407568	NO
1_6_S4D	03-12-19	1.985	1.992	30.00	891.9	15.51	30	0	10	72	20	1665.04	0.9666	684.51	0.1860	8912.9	1339195	NO
1_7_E4C	03-05-19	2.007	2.001	30.00	1006.6	15.70	28	5	15	72	20	1501.62	0.9720	386.05	0.1272	7827.5	1081126	NO
1_7_E4D	03-12-19	1.998	2.012	30.06	1068.7	14.75	30	0	20	72	20	1644.29	1.3321	486.30	0.1800	8601.3	957949	NO
1_7_S1D	03-08-19	1.987	2.003	30.06	1007.1	14.53	24	0	20	72	20	1664.12	0.8802	422.82	0.1351	8841.2	1144479	NO
1_7_S2C	03-09-19	1.998	2.003	30.06	1095.1	14.68	24	0	25	72	20	1775.36	1.4116	405.12	0.1463	9328.7	990224	NO
1_7_W3C	03-17-19	1.985	1.989	30.00	965.4	12.85	40	50	10	72	20	1874.85	0.9683	641.48	0.1571	10051.1	1491839	NO
1_9_E4D	03-15-19	1.968	1.986	30.19	849.1	14.15	26	15	7	72	20	1590.88	0.6627	674.29	0.1688	8689.9	1486857	NO
1_9_N2C	03-12-19	1.988	1.992	30.00	815.5	14.70	20	0	10	72	20	1427.31	0.4918	949.86	0.2584	7617.3	1319380	NO

TABLE B.3: STATIC BENDING DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_9_S1D	03-02-19	1.998	2.009	29.70	834.1	13.82	38	0	15	72	20	1458.89	0.7889	729.22	0.2118	7642.9	1237060	NO
1_9_W3C	03-02-19	2.003	1.997	30.25	829.6	14.61	18	0	15	72	20	1359.56	0.6249	332.64	0.0922	7129.6	1289955	NO
1_9_W4D	03-18-19	2.000	1.991	30.00	817.4	13.42	24	0	10	72	20	1528.17	0.5086	841.06	0.2066	8062.0	1437567	NO
D_20_S3C	02-15-19	2.013	2.002	30.00	856.3	6.77	20	0	15	75	24	2176.67	0.8148	526.28	0.1346	11273.1	1370011	NO
R_5_S1H	03-03-19	2.002	2.005	29.88	882.5	16.23	18	0	15	72	20	1344.60	0.8270	498.96	0.1459	7030.0	1215241	NO
1_11_N4I	03-09-19	1.995	2.006	30.06	898.1	16.52	28	0	10	72	20	1248.78	0.4154	1272.13	0.3449	6571.6	1317664	YES
1_11_N4J	03-09-19	1.998	2.000	30.13	924.0	16.24	20	50	10	72	20	1306.92	0.4269	396.73	0.0989	6877.5	1467208	YES
1_11_S3I	03-08-19	1.996	1.998	30.06	890.6	16.18	26	0	10	72	20	1374.36	0.5663	653.84	0.1840	7254.2	1263778	YES
1_12_N3C	03-12-19	1.989	1.985	30.00	1037.5	13.48	24	0	20	72	20	1418.30	0.3681	448.30	0.0960	7588.3	1705988	YES
1_12_N4D	03-09-19	1.997	1.999	30.06	1047.1	14.16	24	0	20	72	20	1317.29	0.3410	545.81	0.1212	6942.5	1623866	YES
1_12_S3C	03-05-19	2.009	2.003	30.13	977.5	15.66	28	35	10	72	20	1472.32	0.3818	614.32	0.1287	7651.8	1669168	YES
1_12_S4H	03-16-19	1.994	1.982	30.00	929.0	13.33	24	0	15	72	20	1552.58	0.4886	361.02	0.0899	8277.6	1459358	YES
1_14_N4D	03-09-19	2.007	1.991	30.00	872.9	15.96	28	0	10	72	20	1428.99	0.5479	466.46	0.1271	7488.3	1309710	YES
1_15_E3C	03-22-19	1.929	1.923	29.88	861.1	13.56	20	0	20	72	20	1326.29	0.6117	400.24	0.1303	7787.5	1266053	YES
1_1_E4D	03-22-19	1.996	1.969	29.88	811.5	14.56	25	50	10	72	20	1333.16	0.4692	557.56	0.1447	7140.4	1419098	YES
1_1_N1H	03-09-19	1.991	1.996	30.00	906.2	16.18	20	0	10	72	20	1285.55	0.5903	401.92	0.1192	6826.4	1228895	YES
1_1_S3G	03-16-19	1.973	1.974	30.00	839.8	13.90	20	25	10	72	20	1446.99	0.5439	831.76	0.2543	7911.7	1210668	YES
1_1_S4D	03-18-19	1.995	1.995	30.00	843.1	13.31	18	50	10	72	20	1436.31	0.5388	1558.99	0.4325	7600.2	1277415	YES
1_20_N3K	03-17-19	2.011	2.008	30.00	887.5	14.02	16	0	15	72	20	1390.53	0.5113	362.70	0.1020	7194.5	1248267	YES
1_21_N4H	03-02-19	2.002	1.999	30.25	931.0	16.82	26	0	15	72	20	1485.14	0.5885	627.75	0.1683	7788.1	1321634	YES
1_22_N3G	03-05-19	2.002	1.996	30.00	948.7	14.56	22	0	15	72	20	1492.77	0.5727	1454.47	0.3432	7839.8	1497064	YES
1_28_N4D	03-05-19	1.998	1.999	30.00	884.0	18.73	20	20	10	72	20	1307.22	0.9736	382.23	0.1058	6882.5	1316814	YES
1_2_S3C	03-11-19	2.005	2.020	30.00	921.4	14.75	40	0	10	72	20	1548.00	0.7093	1052.55	0.2506	8009.3	1462766	YES
1_5_E4H	03-02-19	2.008	2.008	29.81	876.4	17.10	16	25	15	72	20	1302.49	0.7225	405.73	0.1281	6759.1	1123868	YES
1_5_N3C	03-02-19	2.007	2.008	30.25	891.9	16.46	25	10	10	72	20	1436.01	0.6934	583.80	0.1835	7459.4	1116672	YES
1_5_N4D	03-04-19	2.001	1.999	30.06	903.5	15.91	24	5	10	72	20	1254.73	0.8954	360.41	0.1025	6586.4	1265767	YES
1_5_S1D	03-09-19	2.003	1.998	30.00	913.8	15.58	26	0	15	72	20	1391.91	0.7125	493.01	0.1560	7295.5	1126681	YES
1_5_S1H	03-03-19	2.015	2.009	30.13	900.3	14.96	16	0	10	72	20	1372.22	0.6074	434.11	0.1226	7068.0	1245923	YES
1_5_S2C	03-17-19	1.999	1.987	30.06	887.9	13.34	22	0	10	72	20	1449.59	0.6670	703.28	0.2018	7670.5	1240834	YES
1_9_N1D	03-17-19	1.889	2.057	30.06	789.6	13.07	26	0	10	72	20	1301.88	0.6588	588.84	0.1918	7452.1	1254456	YES
1_9_S2C	03-18-19	1.999	1.999	30.06	845.3	12.54	24	0	15	72	20	1463.01	0.5541	940.86	0.2790	7695.1	1199925	YES

TABLE B.4: PARALLEL COMPRESSION DATA, GREEN WOOD

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_10_E3B	05-25-19	2.008	1.997	7.72	387.3	82.49	30	65	15	70	48	11561.58	0.02950	7659.91	0.01139	2883.20	1003854	NO
1_10_N1A	10-15-19	1.972	1.967	7.82	265.6	33.30	35	0	20	72	38	11535.64	0.01232	6828.31	0.00656	2973.93	1605503	NO
1_10_N2C	05-25-19	2.009	2.024	7.72	267.4	32.22	26	0	15	70	48	12519.84	0.01427	9974.67	0.01104	3078.99	1329983	NO
1_10_N3D	10-29-19	2.017	1.982	7.96	372.7	108.65	22	75	20	72	28	9576.42	0.01496	7904.05	0.01094	2395.49	1081919	NO
1_10_S1C	10-14-19	1.984	2.006	7.92	268.2	33.01	26	0	20	72	38	11318.97	0.01088	7748.41	0.00731	2844.03	1593784	NO
1_10_W4A	10-29-19	2.026	2.011	7.97	287.0	47.14	22	60	20	72	28	11543.27	0.01291	8985.90	0.00938	2833.20	1407097	NO
1_11_W3D	10-08-19	1.962	1.979	7.94	246.4	30.75	22	0	15	72	42	10299.68	0.01302	8430.48	0.01021	2652.64	1273623	NO
1_12_N3J	10-26-19	1.995	2.004	7.80	267.9	36.86	24	0	20	70	40	11489.87	0.01776	11116.03	0.01708	2873.92	974741	NO
1_12_N3L	10-08-19	2.005	2.000	7.88	274.8	38.58	20	0	25	72	42	10205.08	0.01737	8435.06	0.01304	2544.91	965447	NO
1_12_N4A	10-26-19	1.902	1.931	7.83	211.0	33.17	24	0	15	70	40	9207.15	0.01110	7240.30	0.00828	2506.87	1426117	NO
1_12_N4G	10-29-19	2.013	2.008	7.79	261.4	31.93	22	0	25	72	28	12400.82	0.01520	9204.10	0.00949	3067.91	1437232	NO
1_12_N4K	10-09-19	1.999	2.004	7.95	272.0	36.00	20	0	25	72	39	11471.56	0.02140	10134.89	0.01742	2863.60	869344	NO
1_12_S3D	10-09-19	1.991	1.989	6.71	229.1	33.13	24	0	25	70	39	12815.86	0.01428	10073.85	0.00979	3236.25	1555039	NO
1_12_S4C	10-29-19	2.018	2.001	7.23	260.5	32.81	26	0	25	72	28	12358.09	0.02423	8981.32	0.01292	3060.44	1030341	NO
1_12_S4G	10-29-19	2.000	2.009	7.41	238.4	34.46	24	0	10	72	28	12248.23	0.00988	10670.47	0.00938	3048.34	1694770	NO
1_12_S4I	10-09-19	1.972	1.998	7.94	260.5	37.27	20	0	25	70	39	10490.42	0.02146	7405.09	0.01208	2662.51	931424	NO
1_12_W3J	10-15-19	2.001	2.008	7.96	280.4	39.32	20	0	25	72	38	11170.96	0.02002	8120.73	0.01203	2780.22	1006290	NO
1_14_N3D	10-23-19	2.012	2.008	7.96	254.3	39.50	25	10	15	72	28	11257.93	0.01047	7467.65	0.00724	2786.55	1528722	NO
1_14_S4C	05-25-19	2.020	2.009	7.76	276.4	32.55	26	0	15	70	48	12460.33	0.01849	6376.65	0.00840	3070.42	1119817	NO
1_15_E3D	10-30-19	2.002	2.006	7.62	258.6	31.90	18	0	25	72	24	12519.84	0.02469	12249.76	0.02550	3117.48	716142	NO
1_15_N4A	10-29-19	2.017	1.996	7.89	237.4	30.85	20	0	20	72	28	10733.03	0.02629	10144.04	0.02456	2665.97	614122	NO
1_15_S1A	10-23-19	1.991	2.227	7.21	259.1	33.82	22	0	25	72	28	12106.32	0.01683	7049.56	0.00806	2730.37	1180447	NO
1_15_S1C	05-25-19	2.023	2.020	7.64	256.7	32.61	28	0	15	70	48	12167.36	0.01263	10009.77	0.01013	2977.48	1448262	NO
1_15_S4A	10-23-19	2.008	2.003	7.99	275.9	46.49	24	5	20	72	28	11410.52	0.01088	9051.51	0.00860	2837.01	1567460	NO
1_15_W4A	10-16-19	1.978	1.979	7.91	249.0	35.81	20	0	15	72	32	11219.79	0.01589	9947.21	0.01267	2866.24	1200594	NO
1_16_W4C	10-23-19	2.036	2.029	7.94	277.4	41.08	24	10	20	72	32	11024.47	0.01246	8372.50	0.00887	2668.69	1368819	NO
1_17_N3D	10-08-19	2.000	1.993	7.41	262.7	33.32	32	0	20	72	42	13908.39	0.01252	11978.15	0.01038	3489.31	1733618	NO
1_17_S4C	05-25-19	2.010	2.012	7.80	278.5	31.48	32	0	15	70	48	15084.84	0.01183	12400.82	0.00987	3730.07	1861004	NO
1_19_N1C	10-16-19	1.962	2.009	7.85	260.4	41.99	26	0	15	72	32	11291.50	0.01049	6864.93	0.00627	2864.66	1663359	NO
1_19_S2D	05-25-19	2.008	2.008	7.59	245.9	34.61	28	0	10	70	48	11865.23	0.01226	8554.08	0.00867	2942.72	1464788	NO
1_1_N2D	10-09-19	1.984	1.995	7.99	264.3	33.53	22	0	20	70	39	11007.69	0.01885	9298.71	0.01275	2781.07	1102944	NO
1_1_S1B	05-25-19	2.018	2.011	7.19	232.8	31.67	26	0	10	70	48	11193.85	0.01173	10234.07	0.01004	2758.33	1503600	NO
1_1_S2H	10-26-19	2.008	2.018	7.21	239.6	30.91	26	0	25	70	40	11706.54	0.02274	8587.65	0.01401	2888.97	905522	NO
1_1_S4G	10-29-19	2.020	2.008	7.90	281.1	46.46	18	15	20	72	28	11172.49	0.01758	10446.17	0.01656	2754.45	931201	NO
1_1_W3B	10-08-19	1.983	1.974	7.97	265.5	30.08	20	0	35	72	42	11753.85	0.01781	8752.44	0.01122	3002.69	1193423	NO

TABLE B.4: PARALLEL COMPRESSION DATA, GREEN WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_1_W4G	05-25-19	2.010	2.019	7.77	313.8	70.31	20	25	10	70	44	10272.22	0.01848	7485.96	0.01263	2531.23	874224	NO
1_20_E4A	10-09-19	2.002	2.002	7.92	224.7	36.02	22	5	15	70	40	8306.89	0.01250	6251.53	0.00824	2072.57	1133575	NO
1_21_E3D	10-09-19	2.018	2.020	7.93	255.1	38.33	2	5	15	70	39	10575.87	0.01127	7281.49	0.00726	2594.44	1473597	NO
1_21_E4A	10-26-19	2.005	2.022	7.89	247.2	34.81	25	0	15	70	40	10556.03	0.01025	7386.78	0.00695	2603.79	1570711	NO
1_21_N1C	10-08-19	1.971	1.992	7.32	224.2	35.19	22	0	20	72	42	10437.01	0.01126	7255.55	0.00700	2658.28	1579555	NO
1_21_N3H	10-08-19	2.006	2.001	7.96	255.7	33.61	24	0	20	72	42	11549.38	0.01109	10211.18	0.01011	2877.27	1507014	NO
1_21_N4A	05-25-19	2.009	1.902	7.74	233.7	40.07	24	10	15	70	48	10223.39	0.01065	7894.90	0.00765	2675.50	1617490	NO
1_21_S1A	05-25-19	1.988	1.998	7.82	252.9	35.55	26	0	10	70	48	11396.79	0.01217	9548.95	0.00942	2869.27	1528355	NO
1_21_S1H	10-09-19	1.999	1.915	6.97	211.5	34.75	24	0	20	70	40	10351.56	0.01198	7995.61	0.00802	2704.11	1559150	NO
1_21_S2B	10-08-19	2.004	1.998	7.89	251.9	33.21	26	0	20	72	42	10704.04	0.00917	9860.23	0.00884	2673.34	1668752	NO
1_21_S2D	10-26-19	2.025	2.020	7.47	244.8	31.88	26	0	20	72	40	12521.36	0.01142	10417.18	0.00876	3061.08	1741373	NO
1_21_S3H	10-08-19	1.992	1.994	7.44	236.7	33.89	24	0	20	72	42	10662.84	0.01339	9056.09	0.01005	2684.47	1358370	NO
1_21_W3B	10-29-19	2.003	2.007	7.59	237.1	31.90	25	0	20	72	28	10881.04	0.01191	7978.82	0.00775	2706.71	1532763	NO
1_21_W4C	10-16-19	1.981	1.995	7.37	224.8	32.77	24	0	20	72	32	10021.97	0.01047	7238.77	0.00669	2535.86	1640480	NO
1_22_S4G	10-27-19	2.020	2.029	7.08	239.0	32.04	22	0	20	72	38	12792.97	0.01073	11056.52	0.00906	3121.32	1783307	NO
1_23_N3D	10-08-19	1.977	1.997	7.96	286.0	41.03	32	5	20	72	42	11842.35	0.01251	8653.26	0.00847	2999.53	1548865	NO
1_23_N4C	10-23-19	2.003	2.001	7.78	281.0	36.33	34	0	20	72	28	12249.76	0.01442	9863.28	0.01174	3056.33	1254534	NO
1_23_S4C	10-27-19	2.015	2.014	7.96	288.5	35.93	35	5	20	72	38	12806.70	0.01100	8711.24	0.00689	3155.75	1864423	NO
1_25_N3D	10-08-19	1.989	1.984	6.89	210.6	34.71	36	0	15	72	42	10356.14	0.01152	9251.40	0.01014	2624.35	1384007	NO
1_25_S3D	10-14-19	2.006	2.013	7.86	267.2	50.51	32	5	20	72	38	10086.06	0.01825	8317.57	0.01300	2497.74	948307	NO
1_28_N3B	10-27-19	2.011	2.018	7.98	264.9	34.24	24	0	20	72	38	10937.50	0.01228	8691.41	0.00914	2695.16	1402232	NO
1_29_N1C	10-26-19	2.023	1.997	7.87	315.4	39.38	30	0	30	70	40	13244.63	0.02354	6018.07	0.00782	3278.43	1140991	NO
1_29_W4C	10-29-19	2.009	2.005	7.96	274.6	34.88	40	5	15	72	28	11006.16	0.02209	8392.33	0.01360	2732.38	917053	NO
1_2_S4D	10-26-19	2.013	2.014	7.05	263.1	37.19	35	0	20	70	40	12545.78	0.01421	10375.98	0.00965	3094.53	1587564	NO
1_30_S4C	10-27-19	2.022	2.011	7.98	283.9	35.65	40	0	20	72	38	11369.32	0.01132	11331.18	0.01142	2796.03	1461356	NO
1_4_E2C	10-14-19	2.000	2.011	7.96	315.4	58.36	25	30	20	72	38	11315.92	0.01731	7856.75	0.01144	2813.51	1022082	NO
1_4_N2C	10-26-19	2.008	2.005	7.52	233.2	32.08	30	0	15	72	40	10955.81	0.01541	9317.02	0.01234	2721.24	1122398	NO
1_4_N2D	10-27-19	2.013	2.005	7.01	227.3	31.69	28	0	20	72	38	12928.77	0.01377	12043.76	0.01261	3203.31	1417182	NO
1_4_W3D	10-15-19	2.056	2.057	8.00	331.1	66.62	24	30	20	72	38	11836.24	0.00947	8399.96	0.00763	2798.70	1558495	NO
1_5_N2D	05-25-19	2.020	2.014	7.69	239.2	32.56	22	0	10	70	48	10365.29	0.01301	8062.74	0.01001	2547.83	1185373	NO
1_5_N2J	05-25-19	2.012	2.011	7.23	232.6	32.25	16	0	15	70	48	10006.71	0.01954	5191.04	0.00733	2473.16	1047280	NO
1_5_N4E	10-16-19	1.999	2.011	7.92	283.0	50.27	22	5	20	72	32	10232.54	0.01784	9681.70	0.01689	2545.42	853563	NO
1_5_S1G	10-09-19	2.020	2.012	7.81	255.1	33.04	18	0	20	70	39	10304.26	0.02132	8155.82	0.01450	2535.35	828384	NO
1_5_W3H	05-25-19	2.017	2.010	7.71	240.8	34.97	20	10	10	70	48	9922.79	0.01488	8189.39	0.01077	2447.55	1123160	NO
1_5_W3J	10-14-19	1.988	2.003	7.94	249.6	34.69	18	0	20	72	38	9434.51	0.01065	7353.21	0.00816	2369.31	1355470	NO

TABLE B.4: PARALLEL COMPRESSION DATA, GREEN WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_5_W4I	05-25-19	2.003	2.005	7.76	277.5	63.03	24	50	10	70	48	9317.02	0.00979	6269.84	0.00653	2319.97	1431471	NO
1_7_N1C	10-27-19	2.013	2.020	7.91	286.7	34.47	20	0	20	72	38	10809.33	0.03493	7975.77	0.02188	2658.30	536620	NO
1_7_N2D	10-29-19	1.965	1.971	7.75	265.5	32.81	26	0	20	72	28	10607.91	0.03417	9072.88	0.02614	2738.93	536571	NO
1_7_W4C	10-29-19	1.955	1.963	7.93	261.0	33.25	32	0	20	72	28	10195.92	0.02115	7875.06	0.01407	2656.80	873248	NO
1_10_N4C	10-27-19	2.015	2.029	7.37	342.7	95.16	25	50	20	72	38	9472.66	0.00918	7786.56	0.00814	2316.94	1401307	YES
1_11_E4C	10-09-19	2.003	2.000	7.94	288.0	35.97	22	5	20	70	39	9323.12	0.01438	7908.63	0.01350	2327.29	875586	YES
1_11_S1C	10-16-19	1.918	1.832	7.89	222.6	33.92	20	0	20	70	32	8068.85	0.01467	6802.37	0.01335	2296.35	868212	YES
1_12_E4A	10-14-19	1.959	1.999	7.97	241.2	33.64	30	0	15	72	38	10446.17	0.01174	8261.11	0.00826	2667.53	1528999	YES
1_12_N4C	10-15-19	2.012	2.010	7.94	254.0	39.16	22	5	15	72	38	10151.67	0.00785	9332.28	0.00825	2510.23	1674735	YES
1_12_S3B	10-26-19	2.000	2.014	7.96	284.4	34.06	36	0	25	70	40	10607.91	0.02111	8203.13	0.01084	2633.54	1124654	YES
1_16_E3D	10-26-19	1.916	2.023	7.97	325.7	67.32	24	30	20	70	40	10174.56	0.01836	9779.36	0.01804	2624.97	837500	YES
1_16_E4C	10-23-19	1.999	1.997	7.41	288.3	56.57	26	10	25	2	28	9832.76	0.02607	8641.05	0.01787	2463.12	725163	YES
1_16_N3D	10-27-19	1.933	1.924	7.96	237.4	35.63	22	0	15	72	38	9597.78	0.01412	8201.60	0.01040	2580.68	1270179	YES
1_16_W3D	10-27-19	2.003	2.013	7.96	281.9	51.45	26	10	20	72	38	10372.92	0.00914	8583.07	0.00821	2572.62	1552479	YES
1_19_E3D	10-27-19	2.023	2.008	7.98	317.5	72.65	22	35	20	73	38	10881.04	0.00911	8912.66	0.00823	2678.62	1596981	YES
1_19_W3D	05-25-19	2.022	2.019	7.49	402.1	124.16	18	85	10	70	44	9506.23	0.00900	9436.04	0.00984	2328.58	1405921	YES
1_1_E3D	10-26-19	1.953	1.985	7.90	268.5	43.12	22	20	20	72	40	9729.00	0.02244	9085.08	0.01926	2509.61	728505	YES
1_1_S4A	10-27-19	2.015	2.020	7.91	277.2	57.25	18	30	20	72	38	9109.50	0.00954	9109.50	0.01069	2238.04	1253541	YES
1_20_S1C	10-09-19	1.997	1.999	7.97	238.9	35.40	18	0	20	70	39	8499.15	0.01815	7279.97	0.01209	2129.04	903447	YES
1_20_S3J	10-09-19	2.010	2.008	7.46	245.7	39.76	20	5	20	70	39	9684.75	0.01941	7519.53	0.01347	2399.55	828047	YES
1_20_S4A	10-30-19	2.011	1.998	7.95	228.9	34.76	18	0	20	72	24	8227.54	0.01195	6454.47	0.00843	2047.68	1140487	YES
1_20_S4C	10-26-19	2.019	2.018	7.92	311.5	60.80	18	0	25	70	40	10260.01	0.01763	5015.56	0.00651	2518.20	1131539	YES
1_20_W4C	10-23-19	2.002	1.998	7.79	244.5	36.25	18	0	25	72	28	9152.22	0.02266	6866.46	0.01375	2288.06	747544	YES
1_21_E4C	10-08-19	1.989	1.992	7.98	316.3	69.55	26	30	15	72	42	9854.13	0.00912	9590.15	0.00909	2487.10	1594354	YES
1_21_N4C	05-25-19	2.010	2.004	7.84	292.6	66.73	24	25	10	70	48	9588.62	0.00980	8451.84	0.00887	2380.47	1416888	YES
1_2_N3D	10-08-19	2.004	2.002	7.96	265.1	33.00	40	0	20	72	42	10585.02	0.01543	8415.22	0.01047	2638.34	1199749	YES
1_4_E3C	10-16-19	1.990	1.980	7.93	304.6	59.37	22	10	20	72	32	10496.52	0.01936	4817.20	0.00795	2663.96	921205	YES
1_5_N1C	10-29-19	1.968	1.942	7.41	218.5	35.73	22	0	20	72	28	9126.28	0.01055	6999.21	0.00683	2387.92	1605602	YES
1_5_W4C	05-25-19	2.011	2.010	7.73	235.2	33.07	22	0	10	70	48	9529.11	0.01249	8039.86	0.00956	2357.46	1245812	YES
1_6_N3D	10-26-19	2.007	1.991	7.89	255.4	33.82	24	0	25	70	40	10588.07	0.01482	8435.06	0.01050	2649.71	1203561	YES
1_6_S3D	10-29-19	2.009	2.002	7.37	231.3	32.98	24	0	15	72	28	9669.49	0.01266	7298.28	0.00749	2404.14	1451381	YES
1_7_S1C	10-16-19	2.009	2.012	7.94	309.9	38.60	23	0	25	72	32	10826.11	0.03106	6292.73	0.01712	2678.33	544407	YES

TABLE B.5: PARALLEL COMPRESSION DATA, SEASONED WOOD

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_10_E3C	05-19-19	1.964	2.010	7.72	252.7	11.81	30	50	15	70	40	26744.08	0.03035	11880.49	0.01050	6774.70	1716668	NO
1_10_N3C	04-07-19	2.003	1.981	7.48	212.7	11.79	28	50	15	72	20	25764.46	0.02273	12446.59	0.00959	6559.38	1977892	NO
1_10_N4D	03-31-19	1.981	1.989	7.08	197.6	11.97	24	60	10	72	20	23793.03	0.02235	12231.45	0.00983	6038.52	1889998	NO
1_10_N4H	04-02-19	1.973	1.965	7.76	231.0	12.25	24	0	10	72	20	25674.44	0.02330	12034.61	0.00989	6622.34	1879877	NO
1_10_S1B	04-07-19	1.987	1.987	7.49	225.5	12.74	26	0	10	72	20	25956.73	0.02588	10943.60	0.00924	6574.37	1795458	NO
1_10_S2C	05-21-19	1.999	1.997	7.69	238.8	10.38	28	0	15	70	40	29122.93	0.02799	16517.64	0.01358	7295.32	1823956	NO
1_10_W3A	05-06-19	1.984	1.988	7.59	230.9	12.03	28	20	10	72	30	25627.14	0.02294	11289.98	0.00917	6497.44	1869323	NO
1_10_W3C	05-21-19	1.843	1.846	7.66	201.9	10.34	30	20	10	70	40	24458.31	0.02284	12782.29	0.01148	7189.02	1960015	NO
1_10_W4B	04-02-19	1.977	1.981	7.39	218.7	11.44	32	20	15	72	20	27050.78	0.02238	13285.83	0.01039	6906.99	1955110	NO
1_10_W4D	03-31-19	2.000	1.982	7.84	239.5	11.97	28	15	15	72	20	28231.81	0.02441	12905.88	0.00962	7122.05	2026774	NO
1_11_E4D	05-21-19	1.844	1.896	7.77	200.5	10.96	22	45	15	70	40	22450.26	0.02608	10191.35	0.00961	6421.29	1815280	NO
1_11_N3D	05-19-19	1.987	1.999	7.68	209.8	10.67	26	20	15	70	40	24954.22	0.02232	11001.59	0.00958	6282.51	1731845	NO
1_11_N4D	05-19-19	2.009	2.003	7.72	213.4	9.82	24	5	10	70	40	27592.47	0.02349	17724.61	0.01442	6856.93	1829021	NO
1_11_N4J	05-21-19	1.882	1.887	7.81	203.0	10.62	20	85	15	70	40	23851.01	0.03057	10610.96	0.01026	6716.07	1743771	NO
1_11_S1D	05-20-19	1.995	1.870	7.69	206.6	10.43	26	0	15	70	40	24961.85	0.02703	10780.33	0.00969	6691.02	1785959	NO
1_11_S2C	04-02-19	2.003	1.990	7.39	214.1	11.93	26	0	10	72	20	24017.33	0.02356	12583.92	0.01086	6025.47	1740677	NO
1_11_W3C	03-30-19	2.004	2.007	7.47	213.1	11.77	26	0	10	72	20	23728.94	0.01848	15045.17	0.01079	5899.75	2076628	NO
1_12_N3I	04-02-19	1.995	1.998	7.42	217.4	13.48	24	0	15	72	20	23622.13	0.02732	11625.67	0.01124	5926.26	1553783	NO
1_12_N3K	04-06-19	1.992	1.985	7.90	230.7	12.31	22	0	15	72	20	24301.15	0.02734	13325.50	0.01215	6145.78	1660309	NO
1_12_N3L	04-07-19	1.994	1.965	7.45	249.7	12.09	26	0	20	72	20	28363.04	0.03993	9736.63	0.00767	7238.78	1940629	NO
1_12_N4B	04-02-19	1.975	1.977	7.93	260.5	12.41	28	0	20	72	20	27912.90	0.04215	8795.17	0.00675	7148.77	1998197	NO
1_12_N4D	03-26-19	2.010	2.009	7.96	271.5	12.75	28	0	20	72	20	26626.59	0.03900	9461.98	0.00793	6593.86	1768897	NO
1_12_N4J	05-20-19	2.001	2.009	6.89	213.1	11.35	22	0	20	70	40	25274.66	0.03309	11344.91	0.01037	6287.22	1629366	NO
1_12_S3C	03-26-19	1.982	1.976	7.46	231.4	11.91	26	0	15	72	20	28317.26	0.02439	10372.92	0.00754	7230.37	2103132	NO
1_12_S3G	05-07-19	1.978	1.975	7.57	223.6	11.57	26	0	15	72	50	27392.58	0.02485	12690.73	0.00962	7011.96	2022201	NO
1_12_S3K	05-21-19	2.005	2.002	7.79	227.9	10.93	18	0	10	70	40	24397.28	0.02856	11775.21	0.01145	6078.03	1533620	NO
1_12_S4B	04-07-19	1.999	1.988	7.46	242.4	12.11	36	0	20	72	20	28749.08	0.03335	12745.67	0.00960	7234.27	2001271	NO
1_13_N3C	04-01-19	2.019	2.005	7.37	223.6	12.72	22	0	10	72	20	22491.46	0.03001	12622.07	0.01215	5556.06	1536958	NO
1_13_S3A	03-30-19	1.999	2.005	7.74	248.0	11.84	44	0	15	72	20	27413.94	0.02897	10273.74	0.00896	6839.81	1713629	NO
1_14_S3C	03-26-19	1.988	1.999	7.28	205.2	14.01	30	0	10	72	20	23370.36	0.02092	10964.97	0.00919	5880.80	1798537	NO
1_15_E4B	03-30-19	1.999	1.997	7.74	222.6	11.95	26	75	15	72	20	24899.29	0.02311	11599.73	0.00904	6237.29	1923948	NO
1_15_N1B	05-20-19	2.000	2.007	7.27	210.6	10.48	26	0	20	70	40	26445.01	0.02440	11828.61	0.01034	6588.19	1706897	NO
1_15_N2A	04-07-19	2.004	2.000	7.29	199.6	9.71	22	0	10	72	20	24584.96	0.02700	10639.95	0.01012	6133.97	1570277	NO
1_15_N2C	04-01-19	2.009	2.007	7.47	231.5	12.60	25	0	20	72	20	24247.74	0.03022	10437.01	0.00940	6013.73	1648433	NO
1_15_N3A	03-26-19	2.006	1.979	7.33	203.6	12.25	26	10	15	72	20	21827.70	0.02145	11843.87	0.01159	5498.34	1541463	NO

TABLE B.5: PARALLEL COMPRESSION DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_15_N4B	03-30-19	1.972	1.969	7.91	224.9	11.98	21	15	15	72	20	23179.63	0.02719	8215.33	0.00671	5969.72	1886863	NO
1_15_S2A	04-07-19	1.933	1.934	7.46	203.0	11.87	24	0	10	72	20	23674.01	0.02480	10371.40	0.00962	6332.62	1726632	NO
1_15_S3A	03-30-19	1.976	1.985	7.58	205.8	11.67	28	50	10	72	20	25445.56	0.02154	12593.08	0.01008	6487.31	1906512	NO
1_15_S3C	04-02-19	1.991	1.980	7.67	217.6	12.07	28	50	10	72	20	27146.91	0.02106	10491.94	0.00847	6886.27	1880436	NO
1_15_S4B	04-05-19	1.998	1.988	7.14	202.7	12.54	26	50	10	72	20	22581.48	0.02035	10144.04	0.00845	5685.13	1809213	NO
1_15_S4D	04-06-19	1.913	1.893	7.63	201.2	12.03	30	0	10	72	20	22840.88	0.02382	21136.47	0.01904	6307.36	1834976	NO
1_15_W3A	03-31-19	1.995	1.993	7.40	216.7	11.54	20	25	10	72	20	26620.48	0.02556	12675.48	0.00993	6695.23	1921532	NO
1_15_W3C	03-30-19	1.992	2.000	7.72	236.4	10.83	22	5	15	72	20	29341.13	0.02534	12683.11	0.00925	7364.74	2061115	NO
1_15_W4B	05-20-19	1.997	1.991	7.74	226.7	10.79	22	0	15	70	40	27090.45	0.02542	12443.54	0.00973	6813.45	1925408	NO
1_15_W4D	05-06-19	1.987	1.985	7.59	220.1	11.66	26	0	15	72	30	25166.32	0.02306	12872.31	0.01090	6380.60	1793003	NO
1_16_E3C	04-02-19	1.977	1.982	7.82	234.3	12.79	24	30	15	72	20	25709.53	0.02838	11791.99	0.00994	6561.21	1812810	NO
1_16_E4D	03-31-19	1.999	1.984	7.88	236.5	12.04	24	10	15	72	20	26098.63	0.02340	13595.58	0.00991	6580.57	2070749	NO
1_16_N1D	03-30-19	1.994	2.002	7.60	219.2	12.43	24	0	10	72	20	24879.46	0.02379	12773.13	0.01050	6232.35	1824942	NO
1_16_N2C	04-05-19	1.990	1.983	7.73	226.5	12.87	24	0	15	72	20	24774.17	0.02390	11418.15	0.00955	6278.03	1814080	NO
1_16_S1D	04-02-19	1.996	1.974	7.82	222.7	12.28	26	0	10	72	20	26237.49	0.02328	11219.79	0.00883	6659.09	1931254	NO
1_16_W3C	03-31-19	2.000	1.994	7.86	224.7	11.94	24	40	10	72	20	25280.76	0.01766	11520.39	0.00831	6339.21	2081942	NO
1_17_E3C	05-20-19	1.995	2.002	7.72	216.2	10.43	22	30	10	70	40	26925.66	0.02495	13208.01	0.01081	6741.54	1832148	NO
1_17_N4D	03-31-19	1.984	1.984	7.09	228.7	12.14	30	0	20	72	20	30920.41	0.01971	16358.95	0.01025	7855.28	2428275	NO
1_17_S3C	03-26-19	1.999	2.006	7.69	250.2	13.74	24	0	10	72	20	27293.40	0.02082	12623.60	0.00907	6806.34	2078982	NO
1_17_S4D	03-30-19	1.977	1.985	7.71	249.8	12.28	34	0	15	72	20	30989.07	0.02036	12704.47	0.00795	7896.62	2438524	NO
1_19_E4D	05-19-19	1.837	1.812	7.42	177.2	11.64	16	85	15	70	40	21397.40	0.02220	14022.83	0.01377	6428.26	1832326	NO
1_19_N1D	05-20-19	2.002	2.005	7.68	219.4	10.53	28	0	10	70	40	28073.12	0.02086	14384.46	0.01038	6993.78	2067279	NO
1_19_N2C	05-21-19	2.005	1.999	7.86	228.2	10.51	32	0	10	70	40	24676.51	0.02440	12742.62	0.01130	6156.82	1684069	NO
1_19_S1D	05-19-19	1.995	1.999	7.64	220.3	10.68	26	0	15	70	40	28643.80	0.02236	12466.43	0.00941	7182.49	1988445	NO
1_19_S2C	05-19-19	2.006	1.977	7.49	210.9	10.52	26	0	10	70	40	27474.98	0.02541	14489.75	0.01265	6927.87	1729701	NO
1_19_S3C	04-06-19	1.977	1.990	7.87	221.4	12.82	28	0	15	72	20	22131.35	0.02466	11474.61	0.01127	5625.33	1549075	NO
1_19_W3C	05-19-19	1.999	1.991	7.61	217.1	10.64	26	50	10	70	40	25869.75	0.02238	10462.95	0.00872	6499.92	1804551	NO
1_19_W4D	05-20-19	1.925	1.920	7.74	203.5	8.92	16	25	15	70	40	27304.08	0.02557	8224.49	0.00708	7387.47	1880678	NO
1_1_E3C	05-21-19	2.001	2.011	7.74	223.6	10.00	22	10	15	70	40	26345.82	0.02794	10720.83	0.00915	6547.15	1742599	NO
1_1_E3G	04-07-19	1.985	1.991	7.48	224.4	12.19	22	35	10	72	20	23017.88	0.03249	9402.47	0.00819	5824.16	1739674	NO
1_1_E4D	04-05-19	1.992	1.950	7.57	210.7	12.75	22	30	10	72	20	21957.40	0.02512	10781.86	0.01023	5652.71	1624598	NO
1_1_N1D	05-07-19	1.963	1.942	7.50	208.3	11.66	24	0	10	72	50	25495.91	0.02492	10879.52	0.00968	6688.07	1764876	NO
1_1_N1H	04-06-19	1.971	1.975	7.92	234.3	12.82	26	0	15	72	20	21907.04	0.02920	9545.90	0.00967	5627.69	1518826	NO
1_1_N2G	04-05-19	1.986	1.987	7.88	245.4	11.79	22	0	10	72	20	26518.25	0.03065	11027.53	0.01012	6719.98	1653771	NO
1_1_S1H	05-21-19	1.997	2.002	7.21	202.9	10.28	26	0	10	70	40	25291.44	0.02593	19935.61	0.01915	6326.03	1559074	NO

TABLE B.5: PARALLEL COMPRESSION DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_1_S3A	05-06-19	1.970	1.987	7.51	201.7	11.36	20	40	10	72	30	23043.82	0.02438	12557.98	0.01208	5886.95	1590018	NO
1_1_S3C	04-05-19	1.984	1.982	6.91	192.8	11.48	20	80	10	72	20	23779.30	0.02605	13520.81	0.01221	6047.19	1686680	NO
1_1_S3G	03-31-19	1.977	1.970	7.96	220.5	12.38	22	35	10	72	20	21289.06	0.02794	9484.86	0.00941	5466.18	1548729	NO
1_1_S3L	05-21-19	2.002	1.711	7.71	186.5	10.86	24	0	10	70	40	21998.60	0.02627	10574.34	0.01118	6422.16	1653377	NO
1_1_S4D	05-07-19	1.987	1.993	7.77	208.8	11.63	18	50	10	72	50	22581.48	0.02091	10461.43	0.00966	5702.26	1636502	NO
1_1_S4H	05-20-19	2.004	1.993	7.77	227.7	9.34	18	0	10	70	40	27529.91	0.03283	12063.60	0.01039	6892.87	1741004	NO
1_1_W3A	04-06-19	1.981	1.979	7.16	221.6	12.74	17	0	20	72	20	20745.85	0.04488	13705.44	0.01734	5291.77	1207247	NO
1_1_W3C	05-19-19	2.000	1.997	7.69	238.4	10.38	24	0	20	70	40	26229.86	0.03067	18507.38	0.01777	6567.32	1561514	NO
1_1_W3G	05-06-19	1.987	1.970	7.59	210.0	11.61	22	0	15	72	30	23036.19	0.02600	15527.34	0.01520	5885.00	1562800	NO
1_1_W4B	04-06-19	1.990	1.926	6.96	194.9	12.09	24	0	10	72	20	25576.78	0.02168	13879.39	0.01085	6673.24	1998227	NO
1_1_W5A	03-31-19	1.993	1.998	7.92	245.7	12.44	24	0	15	72	20	23382.57	0.02784	10348.51	0.01010	5872.05	1539863	NO
1_20_N3K	04-01-19	2.009	2.007	7.61	219.1	12.31	14	0	15	72	20	22840.88	0.02984	9718.32	0.00967	5664.81	1492552	NO
1_20_S3I	03-31-19	1.999	1.997	7.36	207.2	12.36	18	0	10	72	20	23254.39	0.02498	10365.29	0.00969	5825.24	1603959	NO
1_20_S4J	05-20-19	2.001	2.003	7.69	233.6	9.96	20	0	15	70	40	26881.41	0.03765	11547.85	0.01031	6706.93	1673206	NO
1_20_S4L	04-07-19	1.939	1.944	7.45	213.4	12.42	17	0	15	72	20	22001.65	0.03517	10067.75	0.01056	5836.89	1514518	NO
1_21_E4B	03-26-19	1.999	2.010	7.65	216.1	13.64	28	0	10	72	20	21649.17	0.01836	18658.45	0.01605	5388.06	1732141	NO
1_21_N2C	04-05-19	1.954	1.994	7.93	219.8	11.82	28	0	10	72	20	25595.09	0.01886	9199.52	0.00707	6569.12	1999859	NO
1_21_N3A	04-07-19	1.984	1.989	7.47	202.7	14.15	20	15	10	72	20	23583.98	0.01957	13151.55	0.01085	5976.41	1839433	NO
1_21_N3C	04-07-19	1.989	1.994	7.51	208.1	12.01	24	15	10	72	20	24220.28	0.02001	12147.52	0.00893	6106.88	2053272	NO
1_21_N3G	05-07-19	1.929	1.915	6.90	185.0	11.33	26	0	10	72	50	26052.86	0.02122	5604.55	0.00499	7052.68	1820846	NO
1_21_S1D	05-07-19	2.000	2.001	7.44	216.7	11.65	28	0	10	72	50	27738.95	0.01837	14744.57	0.00919	6931.27	2399306	NO
1_21_S2A	04-07-19	1.989	1.981	7.46	205.9	12.72	20	0	15	72	20	23968.51	0.02210	10704.04	0.00940	6083.06	1729822	NO
1_21_S2C	04-06-19	1.992	1.976	7.90	224.2	12.34	24	0	10	72	20	26498.41	0.02006	12831.12	0.00965	6731.99	2021516	NO
1_21_S3G	05-06-19	1.974	1.985	7.58	208.3	11.84	24	0	10	72	30	27160.64	0.02085	12872.31	0.00985	6931.58	1997713	NO
1_21_S4H	03-26-19	1.982	1.992	7.41	214.8	13.07	22	0	10	72	20	25169.37	0.02055	11076.36	0.00834	6374.99	2014136	NO
1_21_W3A	04-07-19	1.994	1.997	7.59	204.0	12.50	26	0	10	72	20	24588.01	0.02036	11495.97	0.00912	6174.76	1895899	NO
1_21_W3C	05-07-19	1.980	1.980	7.37	211.2	11.64	28	0	15	72	50	26675.41	0.02044	18424.99	0.01457	6804.26	1930930	NO
1_21_W4D	05-21-19	1.989	1.998	7.79	220.9	10.06	22	0	10	70	40	29742.43	0.02182	8850.10	0.00661	7484.21	2015974	NO
1_22_N3G	03-31-19	2.003	2.006	7.92	240.1	11.31	22	0	15	72	20	26161.19	0.02263	11427.31	0.00918	6510.97	1854320	NO
1_22_N4H	05-19-19	2.008	2.003	7.49	233.3	11.01	28	0	15	70	40	32502.75	0.02145	13256.84	0.00850	8081.19	2322596	NO
1_22_S3G	03-26-19	1.992	1.990	7.02	220.1	13.67	28	0	15	72	20	23371.89	0.01951	11004.64	0.00863	5895.92	1927045	NO
1_22_S4H	05-20-19	2.005	1.983	7.72	231.9	10.78	24	0	15	70	40	29237.37	0.02537	13304.14	0.01053	7353.62	1901997	NO
1_23_N3C	04-01-19	1.983	1.980	7.90	246.1	12.21	34	0	10	72	20	29324.34	0.92318	12344.36	0.00887	7468.62	2121622	NO
1_23_N4D	04-07-19	1.975	1.972	7.59	235.9	12.21	30	0	10	72	20	27755.74	0.02201	11145.02	0.00775	7126.54	2210633	NO
1_23_S4D	03-31-19	1.967	1.985	7.02	218.6	12.31	28	0	10	72	20	27438.36	0.02120	13409.42	0.00995	7027.38	2066710	NO

TABLE B.5: PARALLEL COMPRESSION DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_25_N4D	05-21-19	1.992	1.997	7.74	212.9	9.49	38	0	10	70	40	25482.18	0.02502	13223.27	0.01212	6405.74	1641967	NO
1_25_S3C	05-19-19	1.995	2.002	7.71	209.2	10.27	35	0	10	70	40	26329.04	0.02428	10968.02	0.00934	6592.17	1760877	NO
1_25_S4D	05-20-19	2.001	2.009	7.78	215.6	10.90	32	0	10	70	40	27848.82	0.02198	11747.74	0.00932	6927.55	1876393	NO
1_27_N3C	03-31-19	1.999	1.970	7.75	230.4	12.65	30	0	10	72	20	26167.30	0.02203	12918.09	0.00983	6644.77	1998120	NO
1_27_N4D	05-07-19	1.998	1.998	7.58	223.6	11.78	82	0	10	72	50	26150.51	0.02113	13946.53	0.01099	6550.72	1903475	NO
1_28_N3C	04-08-19	1.995	1.993	7.49	219.8	11.69	28	0	10	72	20	28135.68	---	---	---	7076.32	---	NO
1_28_N4B	04-06-19	2.002	1.999	7.86	238.4	12.50	32	10	10	72	20	24687.20	0.02390	11817.93	0.01067	6168.72	1656728	NO
1_28_N4D	04-05-19	1.988	1.990	7.82	228.9	12.01	26	0	10	72	20	26258.85	0.02358	10736.08	0.00833	6637.53	1950478	NO
1_28_S4D	05-19-19	1.984	2.007	7.58	223.9	10.29	32	0	15	70	40	27110.29	0.02905	21270.75	0.02022	6808.40	1581450	NO
1_29_E3C	03-31-19	1.982	1.980	7.02	209.6	12.22	38	0	10	72	20	22319.03	0.03163	10939.03	0.01219	5687.30	1369344	NO
1_29_N2C	03-26-19	1.981	1.993	7.35	228.1	13.84	40	0	15	72	20	21162.41	0.03873	6875.61	0.00765	5360.11	1362123	NO
1_29_S1D	05-19-19	2.009	2.010	7.70	248.2	11.49	40	0	15	70	40	25668.34	0.03519	11723.33	0.01095	6356.56	1587699	NO
1_29_S2C	04-06-19	1.996	1.997	7.68	258.3	12.01	48	0	15	72	20	26332.09	0.03087	17732.24	0.01667	6606.12	1597639	NO
1_29_W3C	05-19-19	1.972	2.004	7.52	234.2	10.86	40	0	20	70	40	25320.43	0.04881	9403.99	0.01092	6407.17	1305055	NO
1_2_N3C	05-20-19	2.002	1.998	7.34	219.2	10.25	32	0	10	70	40	27044.68	0.02977	15835.57	0.01398	6761.18	1694907	NO
1_2_N4D	04-01-19	2.009	2.017	7.89	241.1	12.50	34	0	10	72	20	26008.61	0.02794	12634.28	0.01038	6418.47	1799218	NO
1_2_S3C	04-05-19	1.988	1.992	7.24	211.6	12.65	40	10	10	72	20	25402.83	0.02410	11598.21	0.01032	6414.70	1699014	NO
1_30_S3C	05-07-19	1.996	1.990	7.51	236.4	11.55	40	0	20	72	50	23895.26	0.02895	7673.65	0.00669	6015.87	1727921	NO
1_30_S4D	04-05-19	1.915	1.881	7.58	222.7	11.53	30	0	15	72	20	27107.24	0.02515	12834.17	0.00990	7525.37	2155602	NO
1_4_E4D	04-07-19	1.991	1.987	7.59	209.2	12.16	24	0	10	72	20	24833.68	0.02460	12715.15	0.01151	6277.29	1671372	NO
1_4_N1D	04-01-19	1.996	2.002	7.67	222.4	11.63	32	0	10	72	20	27493.29	0.02103	14421.08	0.01083	6880.22	1994968	NO
1_4_S1D	05-19-19	1.988	2.009	7.62	220.7	10.70	24	0	10	70	40	27250.67	0.02768	12567.14	0.01113	6823.09	1692948	NO
1_4_W3D	03-26-19	2.009	2.044	7.94	229.5	12.42	22	10	10	72	20	23472.60	0.02394	10687.26	0.00824	5716.11	1889963	NO
1_4_W4D	04-07-19	1.977	1.955	7.48	205.3	10.67	24	0	10	72	20	26235.96	0.02451	13243.10	0.01061	6788.03	1932941	NO
1_5_E3C	03-31-19	2.005	2.005	7.94	219.5	11.92	18	0	10	72	20	21928.41	0.02929	6913.76	0.00679	5454.79	1516480	NO
1_5_E4D	04-02-19	1.982	2.004	7.94	210.8	12.71	26	65	10	72	20	22363.28	0.02350	11184.69	0.01059	5630.33	1591664	NO
1_5_E4H	03-26-19	1.989	1.990	7.95	221.4	12.25	16	40	10	72	20	21432.50	0.02782	9671.02	0.01009	5414.83	1449669	NO
1_5_E4J	05-19-19	1.996	2.007	7.18	206.0	11.21	17	65	10	70	40	21943.66	0.02488	10072.33	0.00948	5477.74	1588579	NO
1_5_N1D	03-31-19	2.049	2.039	7.95	231.5	11.69	20	0	10	72	20	25578.31	0.02151	13513.18	0.01084	6122.27	1787238	NO
1_5_N1J	04-01-19	1.985	1.974	7.23	204.7	12.01	15	60	10	72	20	23812.87	0.01966	13061.52	0.01037	6077.21	1924526	NO
1_5_N4D	04-07-19	1.983	1.988	7.90	212.1	11.49	26	10	10	72	20	22378.54	0.02388	11213.68	0.01028	5676.66	1656700	NO
1_5_S1H	04-02-19	2.005	1.945	7.79	227.2	12.85	15	10	10	72	20	23791.50	0.02488	8453.37	0.00677	6100.82	1916359	NO
1_5_S2I	04-02-19	1.985	1.993	7.49	216.1	12.53	18	0	10	72	20	22238.16	0.03601	10125.73	0.01149	5621.23	1333308	NO
1_5_S4B	04-01-19	1.982	1.991	7.61	213.8	11.64	25	20	10	72	20	25875.86	0.02178	14132.69	0.01114	6557.22	1924588	NO
1_5_W3C	03-31-19	1.986	2.003	7.02	224.5	11.34	40	10	10	72	20	25418.09	0.03426	11253.36	0.01054	6389.73	1607439	NO

TABLE B.5: PARALLEL COMPRESSION DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	DEFLECT AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_5_W3I	05-19-19	1.993	2.004	7.63	205.0	10.11	18	0	10	70	40	23078.92	0.02453	10443.12	0.01063	5778.44	1472630	NO
1_5_W4D	04-05-19	1.998	1.992	7.85	210.5	12.18	28	0	10	72	20	23072.81	0.02131	8209.23	0.00755	5797.17	1635529	NO
1_5_W4J	04-05-19	1.997	1.995	7.93	219.0	11.41	20	0	10	72	20	25106.81	0.02400	16937.26	0.01522	6301.89	1672762	NO
1_6_N3C	05-21-19	2.001	1.994	7.76	223.6	10.05	24	0	15	70	40	25636.29	0.02773	16151.43	0.01487	6425.15	1629815	NO
1_7_E3C	03-31-19	2.005	1.983	7.96	254.5	12.51	38	20	15	72	20	21577.45	0.05207	8758.55	0.01091	5427.04	1209071	NO
1_7_E4D	04-02-19	2.016	2.022	7.87	275.2	13.14	28	0	15	72	20	22492.98	0.08849	8299.26	0.01194	5517.92	1021247	NO
1_7_N2C	05-19-19	2.004	2.008	7.69	238.5	10.92	26	0	15	70	40	24659.73	0.04833	9829.71	0.00982	6128.12	1489404	NO
1_7_S2C	05-21-19	1.990	1.999	7.83	251.9	11.17	26	0	15	70	40	24475.10	0.03663	10243.22	0.00992	6152.60	1553808	NO
1_7_W3C	05-07-19	1.987	1.972	7.76	242.4	11.65	32	0	10	72	50	26489.26	0.03077	10450.74	0.00897	6760.29	1780580	NO
1_9_E3C	05-19-19	1.816	1.998	7.54	184.0	10.85	24	0	10	70	40	21093.75	0.03175	10607.91	0.01305	5813.56	1340999	NO
1_9_S2C	04-06-19	1.992	1.929	7.11	184.1	12.01	24	10	10	72	20	22471.62	0.02468	10694.88	0.01095	5848.07	1522523	NO
1_9_W3C	04-02-19	2.006	2.005	7.22	190.6	13.48	22	15	10	72	20	20512.39	0.02164	10301.21	0.01085	5100.01	1413946	NO
R_15_E3C	04-02-19	1.935	1.936	7.41	212.2	12.95	18	0	15	72	20	20918.27	0.04256	7830.81	0.00941	5583.92	1330637	NO
R_21_N1D	05-07-19	1.994	2.000	6.99	198.6	11.36	22	0	10	72	50	27313.23	0.01836	7977.30	0.00602	6848.85	1988397	NO
1_11_S3G	05-21-19	2.006	2.000	7.34	226.9	10.76	20	20	15	70	40	22317.50	0.04913	9500.12	0.01112	5562.69	1274947	YES
1_11_S3I	03-31-19	1.998	2.008	7.87	227.8	12.37	22	0	15	72	20	21232.61	0.03345	9768.68	0.01067	5292.30	1366634	YES
1_12_S4J	03-31-19	1.996	1.989	7.69	229.8	12.46	20	0	15	72	20	23092.65	0.02769	10496.52	0.00977	5816.72	1620073	YES
1_15_E3C	04-01-19	1.947	1.928	7.90	225.5	12.21	18	10	20	72	20	21501.16	0.03335	9558.11	0.01040	5727.81	1466355	YES
1_15_N1D	03-26-19	2.076	2.073	7.03	223.8	13.11	32	0	15	72	20	24409.48	0.01565	12112.43	0.00821	5671.94	2052640	YES
1_1_E4B	03-31-19	1.996	1.991	7.87	210.6	12.18	22	10	10	72	20	21629.33	0.02150	15065.00	0.01282	5442.66	1770251	YES
1_1_W4A	04-05-19	1.995	1.997	7.95	228.5	12.49	22	30	10	72	20	22457.89	0.02341	12408.45	0.01109	5637.00	1681391	YES
1_1_W4H	05-19-19	2.009	1.834	7.64	198.2	10.35	18	0	15	70	40	20370.48	0.03977	9996.03	0.01249	5528.69	1300586	YES
1_21_N4H	04-02-19	1.989	2.006	7.88	229.6	13.82	24	0	10	72	20	19747.93	0.01847	10169.98	0.00892	4949.44	1710290	YES
1_5_E3I	04-02-19	1.968	2.161	7.40	226.9	13.83	18	30	15	72	20	19654.85	0.02663	10891.72	0.01099	4621.57	1395152	YES
1_5_N2C	04-06-19	1.986	1.973	7.83	209.0	11.88	22	0	10	72	20	22435.00	0.02183	6602.48	0.00509	5725.58	1982421	YES
1_9_E4D	04-02-19	1.984	1.962	7.64	210.3	12.36	22	25	10	72	20	22520.45	0.01982	10841.37	0.00879	5785.44	1897836	YES
1_9_N2C	04-02-19	1.991	1.996	7.37	196.4	12.71	24	0	10	72	20	21833.80	0.01932	10945.13	0.00974	5494.11	1693763	YES

TABLE B.6: PERPENDICULAR COMPRESSION DATA, GREEN WOOD

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	LOAD AT .1" (lbs.)	LOAD AT PL (lbs.)	DEFLECT AT PL (in.)	STRESS AT PL (psi.)	STRAIN AT PL	MOD ELASTICITY (psi.)	EXCL FLAG
1_10_E4C	09-11-19	1.943	1.948	6.048	258.7	77.66	28	75	20	68	36	2360.23	958.86	0.0165	246.36	0.0085	34074	NO
1_10_N4A	09-10-19	1.978	1.991	6.022	254.4	72.34	22	50	20	68	33	2126.92	1455.08	0.0418	365.78	0.0211	19940	NO
1_10_N4C	09-14-19	2.000	1.992	5.988	267.3	93.88	24	85	20	68	46	2071.38	1160.89	0.0239	291.68	0.0120	31706	NO
1_10_N4E	09-10-19	2.013	2.012	5.999	219.9	32.47	24	0	25	66	36	2230.53	995.03	0.0204	247.52	0.0101	29225	NO
1_10_S1C	09-11-19	2.001	1.971	5.998	204.9	33.59	24	0	10	68	40	2081.15	787.51	0.0143	199.97	0.0072	30069	NO
1_11_E4C	09-11-19	2.004	2.011	5.990	213.7	52.64	22	25	20	67	36	1968.23	900.12	0.0200	224.02	0.0100	24871	NO
1_11_W3D	09-11-19	1.985	1.996	5.973	185.5	33.59	28	0	15	68	36	2128.60	946.35	0.0172	237.30	0.0087	32858	NO
1_12_E4A	09-15-19	1.986	2.000	5.999	185.5	33.76	32	0	20	68	38	2037.66	1119.69	0.0263	280.20	0.0132	24094	NO
1_12_N3D	09-15-19	1.996	1.988	6.037	215.9	31.47	32	0	25	68	38	2559.66	1087.80	0.0242	273.87	0.0121	25951	NO
1_12_N3L	09-10-19	2.006	1.994	5.957	205.1	40.24	20	5	30	68	35	2211.00	878.91	0.0179	220.61	0.0089	27824	NO
1_12_N4C	09-08-19	1.992	1.994	5.999	213.7	31.83	40	0	15	68	48	2110.60	668.34	0.0200	167.75	0.0100	24039	NO
1_12_N4I	09-15-19	1.998	2.001	5.974	205.0	33.89	18	0	30	68	38	2303.16	1251.53	0.0293	313.04	0.0147	25871	NO
1_12_N4K	09-10-19	2.002	1.992	6.037	212.2	36.31	18	0	30	66	38	2092.13	965.73	0.0216	242.64	0.0108	27279	NO
1_12_S3B	09-15-19	1.986	1.759	6.009	186.4	32.78	36	0	20	68	39	1855.93	784.00	0.0233	223.08	0.0117	21425	NO
1_12_S3D	09-10-19	1.991	2.002	6.033	213.3	36.31	32	5	25	68	36	2006.68	941.16	0.0275	235.29	0.0138	19426	NO
1_12_S3J	09-15-19	1.996	1.980	6.019	219.7	56.57	24	0	15	68	38	1876.68	913.70	0.0262	230.96	0.0131	21136	NO
1_12_S4C	09-09-19	1.985	1.985	6.024	218.8	34.23	35	0	20	68	45	2304.08	1156.92	0.0262	291.71	0.0132	27440	NO
1_12_S4I	09-14-19	2.002	2.008	6.020	201.6	33.36	18	0	20	68	46	2247.31	1073.30	0.0236	267.52	0.0118	29314	NO
1_15_N4A	09-09-19	1.970	2.000	6.018	184.0	33.01	21	0	25	68	45	1684.88	919.65	0.0226	230.14	0.0115	23314	NO
1_15_S4A	09-11-19	1.968	2.006	6.017	223.2	59.72	25	50	25	68	40	1825.26	867.92	0.0214	216.55	0.0109	22579	NO
1_15_W4A	09-11-19	1.984	1.994	5.996	198.2	41.75	23	25	10	68	36	1888.89	849.91	0.0218	213.33	0.0110	21770	NO
1_17_N3D	09-10-19	1.993	1.996	6.017	213.1	35.59	30	0	20	68	34	2245.03	946.35	0.0153	237.30	0.0077	34030	NO
1_19_W1L	09-11-19	2.002	1.955	6.054	203.1	42.83	30	0	20	68	36	1818.54	779.42	0.0188	199.54	0.0094	23256	NO
1_1_E3B	09-11-19	1.935	2.013	6.020	177.0	31.32	20	0	7	68	40	2297.21	1167.91	0.0205	290.38	0.0106	32946	NO
1_1_E3D	09-14-19	1.989	2.003	6.006	196.3	33.12	18	0	20	68	46	2456.51	1292.88	0.0220	323.06	0.0111	37137	NO
1_1_N2D	09-11-19	1.998	1.999	5.981	198.7	33.71	22	0	20	67	36	1867.83	819.24	0.0187	205.12	0.0094	26741	NO
1_1_W3B	09-15-19	1.994	1.971	6.019	203.1	30.77	20	0	25	68	39	2458.50	1237.64	0.0231	314.28	0.0116	33572	NO
1_20_E4A	09-09-19	1.991	1.996	6.023	184.5	38.74	18	10	15	68	45	1913.30	1023.56	0.0251	256.66	0.0126	23498	NO
1_20_N3L	09-15-19	1.992	2.003	5.977	199.8	34.99	16	0	20	68	38	2093.51	831.76	0.0184	207.84	0.0093	25429	NO
1_20_N4A	09-09-19	2.000	1.985	5.989	209.2	60.34	18	20	20	68	43	1464.54	808.41	0.0247	203.83	0.0124	20235	NO
1_20_N4K	09-15-19	1.988	1.978	5.990	189.9	33.97	18	0	20	68	38	1922.46	855.87	0.0222	216.56	0.0112	21961	NO
1_20_S3J	09-14-19	2.013	2.011	6.017	194.2	36.14	20	0	20	68	46	2171.63	999.91	0.0229	248.86	0.0114	25696	NO
1_20_S3L	09-14-19	2.021	2.039	5.999	191.4	33.92	20	0	30	68	46	1743.93	768.59	0.0238	188.66	0.0118	18904	NO
1_20_S4A	09-10-19	1.994	1.996	6.016	178.0	34.85	22	0	15	68	33	1894.23	1092.53	0.0266	273.95	0.0133	26201	NO
1_21_E3D	09-14-19	2.026	2.017	6.026	196.4	40.86	20	0	10	68	48	2009.89	931.55	0.0193	231.16	0.0095	27935	NO

TABLE B.6: PERPENDICULAR COMPRESSION DATA, GREEN WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	LOAD AT .1" (lbs.)	LOAD AT PL (lbs.)	DEFLECT AT PL (in.)	STRESS AT PL (psi.)	STRAIN AT PL	MOD ELASTICITY (psi.)	EXCL FLAG
1_21_E4C	09-14-19	2.003	2.001	6.000	217.4	59.51	25	20	20	68	46	1939.70	1030.58	0.0244	257.77	0.0122	26311	NO
1_21_N1C	09-10-19	1.994	1.997	6.011	245.8	36.82	35	0	25	66	36	2909.85	1555.02	0.0294	389.73	0.0148	30007	NO
1_21_N3H	09-11-19	1.991	1.992	5.987	191.1	33.27	24	0	25	68	36	2124.79	865.48	0.0189	217.46	0.0095	26144	NO
1_21_N4G	09-14-19	2.025	2.039	5.997	195.6	33.93	22	0	25	68	46	1990.81	884.40	0.0238	217.09	0.0117	20967	NO
1_21_S1A	09-08-19	1.984	2.002	5.971	202.5	39.90	30	0	7	68	48	2003.94	902.40	0.0294	225.60	0.0148	24355	NO
1_21_S1C	09-14-19	1.995	1.998	5.968	192.3	35.56	24	0	20	68	46	1820.53	751.95	0.0216	188.36	0.0108	20344	NO
1_21_S2B	09-10-19	1.999	2.003	5.997	192.4	35.15	28	0	5	66	35	1578.06	625.46	0.0201	156.29	0.0100	16611	NO
1_21_S2D	09-15-19	2.066	2.063	5.981	212.5	32.77	24	0	20	68	38	1973.72	1021.88	0.0290	247.92	0.0140	22499	NO
1_21_S3H	09-10-19	1.984	1.951	6.022	185.4	34.59	26	0	7	65	36	1903.69	890.66	0.0250	228.48	0.0126	22562	NO
1_21_W3B	09-09-19	1.999	2.002	6.014	187.4	32.93	30	0	20	68	45	2045.14	892.03	0.0188	223.01	0.0094	27768	NO
1_22_S4G	09-15-19	1.965	1.961	5.987	194.9	31.81	20	0	20	68	38	2319.03	915.37	0.0193	233.63	0.0098	28034	NO
1_23_N3D	09-14-19	1.980	2.000	5.997	207.4	36.43	32	0	15	68	46	1870.73	810.70	0.0228	202.88	0.0115	20711	NO
1_25_N3D	09-15-19	1.979	1.986	6.014	196.1	33.89	28	0	20	68	38	1928.56	861.36	0.0235	217.07	0.0119	20577	NO
1_25_S3D	09-15-19	1.990	2.015	5.969	181.4	34.27	28	5	15	68	38	1734.31	984.19	0.0321	244.46	0.0161	17085	NO
1_27_N3D	09-10-19	1.992	2.000	6.026	208.1	37.19	26	0	10	65	35	1789.55	762.18	0.0230	190.73	0.0115	18535	NO
1_28_S3H	09-15-19	1.958	1.988	5.990	187.5	34.57	28	0	7	68	38	1994.63	980.07	0.0297	246.74	0.0152	18557	NO
1_29_S1C	09-09-19	2.000	2.003	6.029	248.2	47.81	40	0	20	68	45	2462.16	1106.57	0.0246	276.50	0.0123	28461	NO
1_2_N3D	09-14-19	1.991	1.971	5.976	198.8	34.14	36	0	25	68	46	1832.28	801.09	0.0255	203.42	0.0128	18691	NO
1_2_N4C	09-10-19	1.975	1.982	6.029	196.3	32.63	42	0	25	68	35	2020.57	819.40	0.0197	206.92	0.0100	22909	NO
1_2_S4D	09-15-19	1.992	1.999	5.998	217.0	35.46	36	0	20	68	38	2178.96	1079.71	0.0278	270.33	0.0140	26901	NO
1_4_E3D	09-10-19	2.012	2.007	6.010	260.8	81.65	22	80	15	66	36	1733.25	1010.59	0.0302	252.02	0.0150	19872	NO
1_4_N2C	09-11-19	1.986	1.910	6.007	186.4	32.53	36	0	25	68	40	1963.50	664.83	0.0102	174.21	0.0052	40404	NO
1_4_N2D	09-14-19	1.993	1.997	5.995	190.9	32.94	28	0	20	68	46	1981.20	834.50	0.0230	209.15	0.0115	21728	NO
1_4_S2C	09-11-19	1.999	1.997	6.000	196.7	33.41	24	0	15	66	37	2173.16	1015.32	0.0171	254.47	0.0086	34788	NO
1_4_W3D	09-14-19	2.033	2.053	5.980	248.7	66.74	20	50	20	68	46	2004.70	934.14	0.0228	227.73	0.0112	24179	NO
1_5_E3A	09-11-19	1.954	1.982	5.979	199.9	48.09	18	20	20	68	40	2076.26	1109.47	0.0195	280.17	0.0100	30719	NO
1_5_N1I	09-14-19	1.991	1.995	5.997	196.6	36.31	18	0	25	68	46	1885.07	897.22	0.0225	225.09	0.0113	22970	NO
1_5_S1C	09-11-19	1.991	1.987	6.004	177.1	32.02	26	0	25	68	36	1624.76	693.97	0.0229	174.80	0.0115	17277	NO
1_5_S1G	09-15-19	1.991	2.005	6.026	197.5	32.92	16	0	10	68	38	2084.35	1048.89	0.0210	261.83	0.0105	30537	NO
1_5_S2J	09-15-19	1.987	1.979	6.029	201.0	39.88	16	0	20	67	38	1931.31	1080.78	0.0280	273.34	0.0141	25712	NO
1_5_W3J	09-14-19	1.977	1.998	5.992	189.6	42.79	16	0	15	68	46	1686.10	939.33	0.0303	235.30	0.0153	16764	NO
1_5_W4C	09-11-19	1.973	1.979	6.004	180.9	34.51	22	0	25	68	40	2019.50	970.46	0.0245	245.43	0.0124	22605	NO
1_7_W1C	09-14-19	2.009	2.004	6.018	215.0	34.61	22	0	25	68	46	2517.70	1336.06	0.0238	333.68	0.0118	35338	NO
1_12_S4K	09-08-19	1.990	1.997	5.990	202.9	39.32	22	0	25	68	48	1806.49	914.00	0.0403	229.07	0.0202	19436	YES
1_20_N1C	09-11-19	1.966	1.973	5.983	179.8	33.79	24	0	20	68	40	1597.60	765.99	0.0202	194.31	0.0102	22088	YES

TABLE B.6: PERPENDICULAR COMPRESSION DATA, GREEN WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	LOAD AT .1" (lbs.)	LOAD AT PL (lbs.)	DEFLECT AT PL (in.)	STRESS AT PL (psi.)	STRAIN AT PL	MOD ELASTICITY (psi.)	EXCL FLAG
1_20_S1C	09-10-19	2.007	2.007	5.981	186.2	35.01	20	0	20	68	35	1668.09	540.92	0.0154	134.89	0.0077	18797	YES
1_20_W3H	09-15-19	2.002	1.998	6.049	181.2	36.80	24	0	20	68	38	1340.49	614.78	0.0248	154.00	0.0124	14710	YES
1_7_E4C	09-10-19	1.984	2.011	5.988	220.3	30.71	34	0	30	68	35	3354.49	1387.79	0.0180	345.39	0.0091	47062	YES

TABLE B.7: PERPENDICULAR COMPRESSION DATA, SEASONED WOOD

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	LOAD AT .1" (lbs.)	LOAD AT .04" (lbs.)	LOAD AT PL (lbs.)	DEFLECT AT PL (in.)	STRAIN AT PL	MOD ELASTICITY (psi.)	EXCL FLAG
1_10_N4H	05-26-19	1.974	1.970	6.110	181.4	10.25	26	0	15	70	46	4967.65	2701.11	1845.70	0.0292	0.0148	47142	NO
1_10_S2C	05-27-19	1.996	1.996	5.936	182.1	10.96	28	0	15	70	48	5064.39	3479.61	1954.96	0.0222	0.0111	57052	NO
1_10_W3C	06-01-19	1.984	2.002	5.817	166.2	10.25	28	50	10	70	48	4938.35	3824.77	1955.57	0.0190	0.0096	61436	NO
1_11_S1D	06-01-19	1.990	2.001	5.891	168.7	10.60	30	0	15	70	48	4421.08	3162.54	1943.36	0.0250	0.0125	51809	NO
1_11_W3C	05-27-19	1.994	1.993	5.897	172.5	11.31	32	0	15	70	48	4676.82	3250.73	2412.42	0.0298	0.0150	51655	NO
1_12_N3I	06-01-19	1.979	1.993	5.903	173.8	10.28	22	0	15	70	48	4105.53	2773.74	1489.56	0.0213	0.0108	43109	NO
1_12_N3K	05-27-19	1.991	1.997	5.896	174.4	9.85	22	0	15	70	48	5737.61	3830.57	2350.16	0.0259	0.0130	65168	NO
1_12_N4H	06-01-19	1.981	1.997	5.698	179.7	10.00	22	0	15	70	48	4310.30	3214.11	1962.89	0.0234	0.0118	51317	NO
1_12_N4J	05-27-19	2.005	2.003	6.100	189.9	11.46	18	0	20	70	48	4257.81	3231.20	1727.91	0.0176	0.0088	58697	NO
1_12_N4L	05-26-19	1.994	1.993	6.080	181.5	10.67	18	0	20	70	46	4617.62	3076.78	1793.21	0.0233	0.0117	48390	NO
1_12_S3C	05-26-19	1.981	1.973	6.030	184.8	10.00	30	0	15	70	46	4461.67	2548.52	1881.10	0.0300	0.0152	38863	NO
1_12_S3G	05-26-19	1.984	1.986	5.920	172.3	10.26	26	0	10	70	46	4688.72	2678.83	1641.85	0.0246	0.0124	38383	NO
1_12_S4D	06-01-19	1.977	1.981	5.777	184.5	9.65	32	0	15	70	48	5511.48	3689.27	2344.67	0.0255	0.0129	56235	NO
1_13_S3A	05-27-19	1.977	1.985	5.813	173.5	10.15	34	0	20	70	48	5446.17	3527.22	2107.54	0.0240	0.0122	54720	NO
1_15_E3D	05-26-19	1.973	2.003	5.910	172.7	9.78	28	0	15	70	46	4728.09	3988.04	2354.13	0.0227	0.0115	67548	NO
1_15_N1D	05-26-19	2.061	2.070	6.080	197.3	10.52	18	0	20	70	46	5467.83	3329.77	2706.30	0.0333	0.0161	49383	NO
1_15_N4B	05-26-19	1.985	1.990	6.060	182.0	10.40	24	0	15	70	46	4428.71	3783.57	2357.48	0.0217	0.0109	66272	NO
1_15_S2A	06-01-19	1.995	1.997	5.788	160.1	9.91	16	0	15	70	48	3965.76	2568.97	1482.85	0.0227	0.0114	39211	NO
1_15_S3A	05-26-19	1.962	1.970	5.982	169.3	9.76	26	15	10	70	46	5080.57	3862.00	2535.10	0.0273	0.0139	70656	NO
1_15_W4B	05-27-19	2.000	2.000	5.916	174.9	10.72	32	0	10	70	48	3089.81	2195.13	1746.22	0.0312	0.0156	32153	NO
1_16_E4D	05-26-19	1.974	1.963	6.070	176.8	10.28	22	0	10	70	46	3470.76	2727.05	1670.53	0.0235	0.0119	45587	NO
1_16_W4D	06-01-19	1.972	1.973	5.836	162.4	9.01	28	25	10	70	48	3783.26	3074.65	1734.92	0.0201	0.0102	52144	NO
1_17_E3C	05-27-19	2.003	1.997	5.854	166.8	10.86	22	25	15	70	48	3740.54	2805.48	1990.66	0.0284	0.0142	45764	NO
1_19_E4D	05-27-19	1.813	1.836	5.917	140.3	10.95	18	75	15	70	48	4716.19	3492.43	1968.38	0.0239	0.0132	59441	NO
1_19_N1D	05-27-19	2.005	1.996	5.848	164.6	10.71	30	0	10	70	48	4292.91	2822.27	1293.95	0.0183	0.0091	42135	NO
1_19_W3C	06-01-19	2.000	2.000	5.852	163.5	10.64	18	75	10	70	48	4685.97	3291.63	2010.50	0.0250	0.0125	53995	NO
1_1_E3C	05-27-19	1.991	2.008	5.851	163.2	10.64	18	25	15	70	48	4430.85	3459.17	2095.34	0.0238	0.0119	59008	NO
1_1_E3G	06-01-19	1.980	1.995	5.836	176.4	10.12	20	25	15	70	48	4950.56	3392.03	2642.82	0.0318	0.0160	51873	NO
1_1_N1B	05-27-19	1.961	1.977	5.948	153.8	9.19	22	0	10	70	48	4292.30	3093.87	2175.90	0.0297	0.0152	55432	NO
1_1_N2G	05-27-19	1.972	1.972	5.819	177.2	9.71	22	0	15	70	48	5275.27	2759.71	1754.76	0.0265	0.0134	39878	NO
1_1_S1D	05-26-19	1.957	1.970	5.980	172.7	9.84	28	0	15	70	46	3571.47	2610.47	1753.54	0.0256	0.0131	43356	NO
1_1_S1H	05-27-19	1.999	1.986	5.876	172.1	10.82	28	0	15	70	48	4346.01	2685.55	1764.83	0.0251	0.0126	39924	NO
1_1_S2C	05-27-19	1.996	1.973	5.846	163.4	10.38	24	0	10	70	48	3918.46	3072.82	1958.01	0.0248	0.0124	52169	NO
1_1_W3A	06-02-19	1.974	1.976	5.636	164.2	10.05	16	0	20	70	48	4599.30	2652.89	1971.44	0.0317	0.0161	46129	NO
1_20_S3I	06-02-19	1.993	1.999	5.850	163.0	10.34	18	0	10	70	48	4606.32	2652.28	1829.53	0.0293	0.0147	44970	NO

TABLE B.7: PERPENDICULAR COMPRESSION DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	LOAD AT .1" (lbs.)	LOAD AT .04" (lbs.)	LOAD AT PL (lbs.)	DEFLECT AT PL (in.)	STRAIN AT PL	MOD ELASTICITY (psi.)	EXCL FLAG
1_20_S3K	05-26-19	1.974	1.980	6.030	160.1	10.20	24	0	10	70	46	4156.80	2594.91	2005.62	0.0309	0.0157	38115	NO
1_20_S4L	06-01-19	1.928	1.932	5.767	160.9	10.59	18	0	20	70	48	4695.13	3297.12	1949.16	0.0227	0.0118	49114	NO
1_21_N1D	05-27-19	2.118	2.133	5.801	184.7	9.73	24	0	10	70	48	4583.74	3166.50	1884.16	0.0235	0.0111	48933	NO
1_21_N3C	06-01-19	1.979	1.972	5.961	161.6	10.39	22	40	10	70	48	4693.60	3870.54	2179.26	0.0217	0.0110	67749	NO
1_21_N4H	06-02-19	1.977	1.982	5.852	166.0	9.69	24	0	10	70	48	4426.58	3341.06	1974.79	0.0232	0.0117	55329	NO
1_21_S1D	06-01-19	1.979	1.967	5.912	170.4	10.44	28	0	10	70	48	4679.87	3082.58	1621.40	0.0215	0.0109	50297	NO
1_21_W3A	05-27-19	1.981	1.978	5.960	159.2	10.21	26	0	10	70	48	4706.73	3872.07	2220.76	0.0206	0.0104	63934	NO
1_28_N3C	05-27-19	1.988	1.962	5.846	173.3	9.07	32	0	10	70	48	4746.70	2814.03	2196.66	0.0316	0.0159	40347	NO
1_28_N4B	06-01-19	1.756	2.012	5.887	155.4	9.86	30	0	10	70	48	4911.50	3704.22	2121.58	0.0234	0.0133	63286	NO
1_28_N4D	06-02-19	1.980	1.968	5.825	172.7	9.43	32	0	10	70	48	4545.59	2977.91	2103.27	0.0286	0.0144	45863	NO
1_29_N2C	05-27-19	2.011	1.998	5.851	197.9	10.66	45	0	25	72	48	5749.21	3740.23	2501.53	0.0275	0.0137	58189	NO
1_2_N3C	05-27-19	2.000	2.005	5.849	178.0	10.99	45	0	10	70	48	4596.56	2816.77	1873.47	0.0257	0.0128	41366	NO
1_2_N4D	05-26-19	2.003	2.017	6.090	186.3	10.17	40	0	15	70	46	4480.90	2882.39	1677.86	0.0243	0.0121	47569	NO
1_4_W3D	06-01-19	2.055	1.982	5.658	162.1	9.48	28	0	15	70	48	4762.27	3301.70	1967.77	0.0236	0.0115	53241	NO
1_4_W4D	06-01-19	1.923	1.979	5.787	156.0	10.39	28	0	10	70	48	4129.33	3497.93	2296.45	0.0240	0.0125	58991	NO
1_5_E3C	05-27-19	1.973	2.004	5.625	152.4	10.24	18	0	15	70	48	3816.53	2865.91	2265.32	0.0328	0.0166	49513	NO
1_5_E3I	06-01-19	1.954	2.133	5.865	177.9	9.92	16	0	10	70	48	4858.40	3580.93	3143.31	0.0356	0.0182	50714	NO
1_5_E4D	05-26-19	1.963	1.973	6.070	160.3	10.01	20	25	10	70	46	3276.98	2308.96	1734.92	0.0303	0.0154	35607	NO
1_5_N2C	05-26-19	1.970	1.987	5.962	157.6	10.24	26	0	15	70	46	3730.16	2287.90	1522.52	0.0267	0.0136	35017	NO
1_5_S1H	05-27-19	1.963	1.986	5.842	158.5	9.78	16	0	10	70	48	4459.84	3094.48	1977.84	0.0243	0.0124	45614	NO
1_5_W3I	06-01-19	1.988	1.985	5.909	157.6	10.47	22	15	10	70	48	4451.60	3186.04	1795.65	0.0222	0.0112	49777	NO
1_5_W4J	06-01-19	1.998	1.987	5.769	160.2	9.58	16	0	10	70	48	4073.49	2353.52	1487.73	0.0255	0.0127	35621	NO
1_6_N3C	06-01-19	1.994	1.990	5.856	171.3	10.44	26	0	10	70	48	5211.18	3823.55	1912.84	0.0182	0.0091	71261	NO
1_6_S4D	05-27-19	1.969	1.970	5.774	162.7	9.98	24	0	15	70	48	4711.00	3641.36	2431.95	0.0239	0.0122	65724	NO
1_9_E4D	05-27-19	1.950	1.969	5.896	161.2	10.24	26	0	10	70	48	4561.46	3372.19	2359.01	0.0282	0.0144	52911	NO
1_9_S2C	05-26-19	1.991	1.929	5.963	153.9	10.06	28	0	10	70	46	4341.13	3218.69	2301.33	0.0285	0.0143	53866	NO
1_10_W3A	06-01-19	1.977	1.984	5.905	178.5	10.46	40	0	10	70	48	5863.04	4710.39	2784.42	0.0208	0.0105	92083	YES
1_12_S4B	06-01-19	1.994	1.995	5.523	177.2	9.97	22	0	15	70	48	3647.46	2623.60	1733.70	0.0247	0.0124	45618	YES
1_20_S3C	05-27-19	1.967	1.972	5.916	168.1	8.86	22	50	15	70	48	6496.89	4454.35	4164.73	0.0379	0.0193	75497	YES
1_9_S1D	06-01-19	1.990	2.001	5.799	153.2	9.73	26	0	10	70	48	3212.28	2312.93	1510.62	0.0257	0.0129	33595	YES

TABLE B.8: PARALLEL TENSION DATA, SEASONED WOOD

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	EXTENS. AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_10_E4B	07-27-19	0.159	0.366	2.5	76.0	10.50	26	10	10	80	50	758.90	0.0168	625.84	0.0141	13058.63	1529928	NO
1_10_E4D	07-30-19	0.232	0.425	2.5	81.5	9.92	36	0	10	75	50	1428.15	0.0153	1059.49	0.0111	14515.52	1933168	NO
1_10_N1B	07-30-19	0.225	0.425	2.5	83.3	8.02	26	0	10	75	50	1524.66	0.0157	1290.59	0.0127	15962.92	2135782	NO
1_10_S1D	07-30-19	0.217	0.398	2.5	85.4	9.27	44	0	10	75	50	1641.08	0.0185	665.36	0.0069	19001.49	2224978	NO
1_10_S2A	07-27-19	0.181	0.371	2.5	76.5	10.09	22	0	15	80	50	1074.83	0.0224	569.99	0.0102	16027.75	1668845	NO
1_10_W3C	07-28-19	0.182	0.371	2.5	78.9	10.94	32	0	10	75	52	1419.22	0.0188	807.57	0.0103	21104.98	2323449	NO
1_11_E4D	07-28-19	0.188	0.356	2.5	78.4	10.32	32	0	15	75	52	792.92	0.0116			11864.07	2010500	NO
1_11_S2C	07-28-19	0.158	0.382	2.5	70.4	10.01	24	0	20	75	52	685.96	0.0258	393.07	0.0104	11380.11	1249409	NO
1_12_S3K	07-28-19	0.193	0.377	2.5	78.3	9.87	24	0	10	75	52	897.60	0.0164	850.30	0.0154	12352.64	1523813	NO
1_13_N3C	07-30-19	0.233	0.351	2.5	75.6	9.73	28	0	15	75	50	1372.45	-0.0017	940.02	0.0105	16781.63	2179523	NO
1_15_N3A	07-27-19	0.154	0.331	2.5	68.4	10.24	18	0	15	80	50	538.41	0.0199	442.58	0.0117	10612.81	1486841	NO
1_15_W3A	07-28-19	0.196	0.364	2.5	75.1	10.28	26	0	15	75	52	1175.84	0.0171	985.57	0.0141	16481.30	1953807	NO
1_15_W4B	07-28-19	0.200	0.366	2.5	75.6	9.54	28	10	15	75	52	1143.27	0.0156	847.47	0.0114	15618.37	2039579	NO
1_16_W4D	07-27-19	0.167	0.355	2.5	71.7	10.23	30	0	15	80	50	725.40	0.0123	612.18	0.0101	12253.12	2044888	NO
1_17_S3C	07-30-19	0.231	0.418	2.5	88.7	9.91	30	0	15	75	50	1958.54	0.0188	1005.10	0.0089	20327.58	2355727	NO
1_19_E3C	07-28-19	0.171	0.355	2.5	69.9	9.36	18	10	15	75	52	870.06	0.0184	673.83	0.0141	14352.74	1576882	NO
1_19_N2C	07-28-19	0.203	0.308	2.5	74.9	9.34	32	0	10	75	52	1139.37	0.0202	795.52	0.0128	18252.62	1994398	NO
1_19_W3C	07-28-19	0.186	0.334	2.5	72.4	9.63	22	75	15	75	52	928.80	0.0180	611.19	0.0113	14991.08	1740438	NO
1_19_W4D	07-28-19	0.182	0.344	2.5	72.8	9.49	18	0	15	75	52	892.33	0.0148	864.56	0.0145	14273.46	1907892	NO
1_1_E3C	07-28-19	0.185	0.364	2.5	76.1	9.75	20	0	15	75	52	576.93	0.0107			8590.71	1576228	NO
1_1_E3G	07-28-19	0.183	0.323	2.5	78.9	10.33	22	0	15	75	52	648.27	0.0141	493.39	0.0106	10967.36	1576786	NO
1_1_S1H	07-28-19	0.249	0.339	2.5	68.6	9.82	26	0	10	75	52	1143.34	0.0155	779.57	0.0103	13592.23	1800512	NO
1_21_N3C	07-27-19	0.168	0.356	2.5	68.7	10.12	26	0	10	80	50	737.30	0.0134	582.35	0.0102	12327.86	1903064	NO
1_21_N3G	07-28-19	0.165	0.355	2.5	72.8	10.63	28	0	10	75	52	775.07	0.0143	698.17	0.0129	13232.10	1845564	NO
1_21_S1B	07-30-19	0.234	0.389	2.5	76.8	9.25	26	0	15	75	50	1602.63	0.0176	1171.27	0.0127	17666.71	2041065	NO
1_21_S2A	07-27-19	0.174	0.355	2.5	68.8	10.35	22	0	10	80	50	1011.73	--------	--------	--------	16426.25	--------	NO
1_22_N4H	07-27-19	0.170	0.372	2.5	78.7	9.98	30	0	15	80	50	823.59	0.0117			13079.29	2251694	NO
1_23_S3C	07-30-19	0.234	0.346	2.5	82.8	9.31	28	0	10	75	50	1364.37	0.0177	881.88	0.0101	16887.59	2170591	NO
1_23_S4D	07-27-19	0.156	0.378	2.5	80.5	10.17	28	0	15	80	50	1255.04	0.0223	683.82	0.0106	21380.04	2204112	NO
1_25_N2C	07-30-19	0.230	0.404	2.5	72.5	9.74	24	0	10	75	50	1054.92	0.0127	861.28	0.0101	11377.68	1837054	NO
1_25_S3C	07-30-19	0.215	0.344	2.5	66.2	9.46	36	0	10	75	50	866.17	0.0134	771.64	0.0120	11711.27	1734159	NO
1_28_N3A	07-27-19	0.185	0.371	2.5	75.8	10.01	28	0	10	80	50	1063.54	0.0190	815.20	0.0134	15558.53	1782113	NO
1_28_S4D	07-30-19	0.218	0.411	2.5	76.1	9.71	32	0	10	75	50	1282.20	0.0167	973.74	0.0126	14360.91	1737740	NO
1_29_E3C	07-30-19	0.221	0.423	2.5	78.2	9.63	24	0	10	75	50	1125.49	0.0177	792.85	0.0121	12039.49	1407566	NO
1_29_S1D	07-30-19	0.217	0.357	2.5	85.0	9.68	48	0	20	75	50	727.08	0.0121	631.64	0.0106	9420.32	1547295	NO

TABLE B.8: PARALLEL TENSION DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (IN.)	WIDTH (IN.)	LENGTH (IN.)	WEIGHT (GM.)	M.C.% (%)	RINGS (/IN.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMI (%)	MAX LOAD (LBS)	EXTENS. AT MAX (IN.)	LOAD AT PL (LBS)	DEFLECT AT PL (IN.)	MOD RUPTURE (PSI)	MOD ELASTIC (PSI)	EXCL FLAG
1_2_N3L	07-28-19	0.176	0.355	2.5	73.6	9.53	38	0	10	75	52	922.93	0.0171	741.65	0.0137	14771.57	1737209	NO
1_30_S3C	07-30-19	0.248	0.345	2.5	83.4	9.53	42	0	10	75	50	1120.68	0.0153	705.80	0.0092	13098.20	1802127	NO
1_30_S4D	07-30-19	0.235	0.402	2.5	78.1	10.34	26	0	15	75	50	1028.60	0.0135	768.20	0.0103	10911.28	1587903	NO
1_4_E4D	07-30-19	0.210	0.414	2.5	75.4	10.95	26	0	10	75	50	1431.05	0.0167	980.22	0.0112	16460.16	2019572	NO
1_4_W4D	07-30-19	0.220	0.389	2.5	70.4	9.38	24	0	15	75	50	767.97	0.0088	710.07	0.0081	8973.77	2056575	NO
1_5_3EC	07-28-19	0.191	0.353	2.5	74.9	10.61	17	75	15	75	52	744.93	0.0133	469.89	0.0081	11064.34	1718570	NO
1_5_E3I	07-27-19	0.272	0.433	2.5	75.1	10.21	16	0	15	80	50	1194.15	0.0112	431.37	0.0039	10150.91	1865899	NO
1_5_E4J	07-27-19	0.170	0.366	2.5	71.8	10.42	24	25	15	80	50	687.71	0.0173	277.02	0.0062	11100.70	1437421	NO
1_5_S1H	07-27-19	0.184	0.371	2.5	73.5	9.95	16	0	10	80	50	781.71	0.0151	700.38	0.0138	11466.70	1489480	NO
1_5_W3I	07-28-19	0.186	0.349	2.5	67.8	11.02	26	10	10	75	52	785.90	0.0155	718.99	0.0138	12106.85	1600732	NO
1_5_W4D	07-30-19	0.212	0.365	2.5	68.7	9.89	18	0	15	75	50	1175.00	0.0217	977.55	0.0134	15184.84	1888495	NO
1_6_N3C	07-28-19	0.178	0.357	2.5	74.9	9.85	26	25	15	75	52	960.69	0.0157			15160.66	1900961	NO
1_6_N4D	07-30-19	0.221	0.389	2.5	76.1	10.15	22	0	15	75	50	1036.84	0.0204	600.59	0.0108	12076.09	1301399	NO
1_6_S1D	07-28-19	0.186	0.347	2.5	76.6	10.37	32	0	10	75	52	858.31	0.0124			13353.51	2157616	NO
1_6_S4D	07-30-19	0.238	0.368	2.5	73.2	9.43	28	0	10	75	50	1177.83	0.0148	1100.16	0.0127	13466.26	1980091	NO
1_7_N1D	07-30-19	0.223	0.376	2.5	80.0	10.25	34	0	20	75	50	722.43	0.0116	697.63	0.0112	8627.39	1488359	NO
1_7_S2C	07-28-19	0.202	0.359	2.5	80.0	9.86	24	0	15	75	52	958.71	0.0176	738.14	0.0132	13253.10	1545294	NO
1_11_N4I	07-28-19	0.183	0.319	2.5	75.8	10.43	34	0	15	75	52	639.65	0.0121			10974.40	1784749	YES
1_11_S3G	07-28-19	0.174	0.372	2.5	72.9	10.21	26	10	15	75	52	510.33	0.0108			7894.84	1424688	YES
1_12_S3L	07-28-19	0.196	0.365	2.5	76.9	11.02	20	0	15	75	52	712.81	0.0122	640.18	0.0112	10003.04	1599583	YES
1_28_S3C	07-30-19	0.228	0.410	2.5	82.0	10.21	32	0	15	75	50	1025.09	0.0134	850.22	0.0106	10979.21	1724716	YES

TABLE B.9: PARALLEL SHEAR DATA, GREEN WOOD

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	MAX STRESS (PSI.)	EXCL FLAG
R_12_S4I	02-08-19	RAD	PITH GROWTH	2.013	2.020	34.47	75	24	1832.43	450.64	NO
R_12_S4K	02-05-19	RAD	GENERAL GROWTH	2.010	1.941	44.05	75	22	2490.23	638.29	NO
R_12_S4L	02-08-19	RAD	PITH GROWTH	2.012	2.030	38.66	75	24	2253.88	551.83	NO
R_14_N3D	02-05-19	RAD	TYPICAL GROWTH	2.007	1.947	44.32	75	22	1888.73	483.35	NO
R_14_S4C	02-08-19	RAD	GENERAL GROWTH	2.009	2.016	59.00	75	24	1415.10	349.40	NO
R_15_S1A	02-08-19	RAD	PITH GROWTH	2.017	1.976	34.72	75	24	2375.64	596.06	NO
R_16_W4C	02-05-19	RAD	EXTERIOR GROWTH	2.000	1.968	70.41	75	22	1750.03	444.62	NO
R_17_N4C	02-08-19	RAD	GENERAL GROWTH	2.008	2.010	32.79	75	24	2017.52	499.87	NO
R_1_E3D	02-08-19	RAD	EXTERIOR GROWTH	2.007	2.004	35.22	75	24	1620.48	402.90	NO
R_1_S3H	02-08-19	RAD	PITH GROWTH	2.010	2.014	36.74	75	24	1902.01	469.85	NO
R_1_W3B	02-08-19	RAD	GENERAL GROWTH	2.016	1.969	30.32	75	24	2291.41	577.25	NO
R_21_N1C	02-05-19	RAD	PITH GROWTH	2.009	1.981	36.34	75	22	2109.99	530.17	NO
R_23_N3D	02-08-19	RAD	PITH GROWTH	2.009	2.011	35.16	75	24	2175.60	538.50	NO
R_2_N3D	02-05-19	RAD	TYPICAL GROWTH	2.017	1.968	32.93	75	22	1969.91	496.27	NO
R_4_S2D	02-05-19	RAD	GENERAL GROWTH	2.009	1.980	33.92	75	22	2143.10	538.76	NO
T_12_N3L	02-05-19	TAN	TYPICAL GROWTH	2.010	2.028	35.29	75	22	2053.53	503.77	NO
T_12_S4I	02-08-19	TAN	PITH GROWTH	2.006	2.025	37.58	75	24	2100.53	517.10	NO
T_12_S4K	02-05-19	TAN	GENERAL GROWTH	2.020	1.957	39.19	75	22	1939.39	490.60	NO
T_12_S4L	02-08-19	TAN	PITH GROWTH	2.004	2.013	38.08	75	24	1981.96	491.31	NO
T_14_N3D	02-05-19	TAN	TYPICAL GROWTH	2.012	1.935	44.69	75	22	1552.43	398.75	NO
T_14_S4C	02-08-19	TAN	GENERAL GROWTH	2.015	1.964	56.90	75	24	1767.27	446.57	NO
T_15_S1A	02-08-19	TAN	PITH GROWTH	2.015	2.005	35.99	75	24	2207.64	546.44	NO
T_15_S4A	02-05-19	TAN	EXTERIOR GROWTH	2.007	2.006	46.75	75	22	1632.23	405.42	NO
T_16_W4C	02-05-19	TAN	EXTERIOR GROWTH	2.007	1.993	96.66	75	22	1918.64	479.67	NO
T_17_N4C	02-08-19	TAN	GENERAL GROWTH	2.025	2.013	38.34	75	24	2482.76	609.07	NO
T_1_E3D	02-08-19	TAN	EXTERIOR GROWTH	2.008	1.974	35.49	75	24	1612.09	406.70	NO
T_1_S3H	02-08-19	TAN	PITH GROWTH	2.002	1.971	36.45	75	24	2164.76	548.61	NO
T_1_W3B	02-08-19	TAN	GENERAL GROWTH	2.012	1.987	30.55	75	24	1963.20	491.06	NO
T_20_E4A	02-05-19	TAN	EXTERIOR GROWTH	1.999	1.974	34.11	75	22	1600.80	405.67	NO
T_21_N1C	02-05-19	TAN	PITH GROWTH	2.010	1.963	35.74	75	22	2017.37	511.29	NO
T_23_N3D	02-08-19	TAN	PITH GROWTH	2.011	2.007	35.88	75	24	1787.11	442.78	NO
T_2_N3D	02-05-19	TAN	TYPICAL GROWTH	2.009	1.993	32.60	75	22	1675.11	418.37	NO
T_4_S2D	02-05-19	TAN	GENERAL GROWTH	2.001	1.938	32.72	75	22	1446.84	373.09	NO
T_5_W3J	02-05-19	TAN	EXTERIOR GROWTH	2.016	1.994	33.31	75	22	1674.65	416.59	NO
R_12_N3L	02-05-19	RAD	TYPICAL GROWTH : N	2.014	1.959	35.38	75	22	2291.11	580.70	YES

TABLE B.9: PARALLEL SHEAR DATA, GREEN WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	MAX STRESS (PSI.)	EXCL FLAG
R_20_E4A	02-05-19	RAD	EXTERIOR GROWTH :	2.001	1.898	34.29	75	22	1644.44	432.99	YES
R_5_W3J	02-05-19	RAD	EXTERIOR GROWTH :	2.016	1.969	33.19	75	22	2134.55	537.74	EYS

TABLE B.10: PARALLEL SHEAR DATA, SEASONED WOOD

SAMPLE NUMBER	DATE	SURFA	LOCATION	WIDTH (in.)	LENGTH (in.)	LENGTH (in.)	SHEAR AREA (in^2)	M.C.% (%)	TEMP (F)	HUMIDI (%)	MAX LOAD (lbs.)	SHEAR STRENG (psi.)	EXCL FLAG
R_10_E3C	06-18-19	RAD	OUTER GROWTH	1.987	1.260	1.260	5.01	11.77	72	60	4937.74	986.12	NO
R_10_N4D	06-25-19	RAD	OUTER GROWTH	1.980	1.233	1.225	4.87	10.75	72	58	3301.39	678.34	NO
R_10_S2A	06-23-19	RAD	TYPICAL GROWTH	1.998	1.223	1.225	4.89	10.25	72	56	3901.98	797.77	NO
R_10_S4H	06-21-19	RAD	OUTER GROWTH	2.004	1.226	1.228	4.92	11.09	70	54	4407.04	896.14	NO
R_10_W4D	06-25-19	RAD	OUTER GROWTH	1.851	1.225	1.221	4.53	11.66	72	58	4669.80	1031.42	NO
R_11_N3C	06-23-19	RAD	OUTER GROWTH	1.989	1.240	1.242	4.94	10.76	72	56	3140.56	636.17	NO
R_11_N4D	06-18-19	RAD	OUTER GROWTH	1.988	1.259	1.263	5.01	10.53	72	60	4267.58	851.18	NO
R_11_N4I	06-23-19	RAD	TYPICAL GROWTH	1.980	1.241	1.243	4.92	10.19	72	56	3731.38	758.67	NO
R_12_N4H	06-21-19	RAD	OUTER GROWTH	1.997	1.234	1.232	4.92	11.22	70	52	4443.67	902.34	NO
R_12_N4J	06-24-19	RAD	TYPICAL GROWTH	2.005	1.274	1.277	5.11	10.69	72	58	5322.27	1040.57	NO
R_12_S3C	06-25-19	RAD	PITH GROWTH	1.990	1.224	1.229	4.88	11.43	72	58	4536.13	929.26	NO
R_12_S3I	06-23-19	RAD	TYPICAL GROWTH	1.995	1.234	1.235	4.93	11.40	72	56	4003.30	812.74	NO
R_12_S4D	06-21-19	RAD	PITH GROWTH	1.994	1.228	1.230	4.90	11.31	70	52	4523.93	923.01	NO
R_13_N3C	06-18-19	RAD	TYPICAL GROWTH	2.003	1.241	1.239	4.97	11.26	72	60	3814.39	767.88	NO
R_13_S3A	06-21-19	RAD	PITH GROWTH	1.929	1.247	1.250	4.82	11.71	70	52	4527.28	939.91	NO
R_15_E3C	06-18-19	RAD	TYPICAL GROWTH	1.976	1.236	1.240	4.89	11.21	72	60	4485.78	916.85	NO
R_15_E4B	06-24-19	RAD	TYPICAL GROWTH	2.002	1.216	1.220	4.88	11.37	72	58	3833.92	786.14	NO
R_15_N1B	06-24-19	RAD	TYPICAL GROWTH	1.909	1.249	1.249	4.77	10.09	72	58	3730.47	782.29	NO
R_15_N1D	06-25-19	RAD	TYPICAL GROWTH	1.987	1.241	1.238	4.93	11.45	72	58	4345.09	882.11	NO
R_15_N2A	06-23-19	RAD	PITH GROWTH	2.000	1.226	1.230	4.91	10.28	72	56	4268.19	868.93	NO
R_15_N2C	06-18-19	RAD	TYPICAL GROWTH	2.009	1.263	1.264	5.08	11.31	72	62	4247.13	836.59	NO
R_15_S2C	06-21-19	RAD	PITH GROWTH	2.003	1.266	1.268	5.08	10.67	70	52	3896.79	767.75	NO
R_16_N1D	06-25-19	RAD	PITH GROWTH	2.000	1.245	1.249	4.99	11.38	72	58	4127.50	827.49	NO
R_19_N1D	06-24-19	RAD	TYPICAL GROWTH	1.996	1.255	1.257	5.01	10.36	72	58	3656.92	729.35	NO
R_19_S1D	06-18-19	RAD	TYPICAL GROWTH	1.987	1.281	1.284	5.10	10.78	72	60	4284.36	840.62	NO
R_1_W3C	06-24-19	RAD	TYPICAL GROWTH	1.981	1.247	1.244	4.93	10.01	72	58	4806.52	974.03	NO
R_1_W4B	06-23-19	RAD	OUTER GROWTH	1.923	1.273	1.278	4.91	10.25	72	56	3746.95	763.82	NO
R_20_N3K	06-24-19	RAD	TYPICAL GROWTH	1.985	1.212	1.213	4.81	11.65	72	58	4262.09	885.42	NO
R_20_S4J	06-23-19	RAD	TYPICAL GROWTH	2.010	1.249	1.253	5.03	11.23	72	56	4414.67	877.84	NO
R_21_E3C	06-21-19	RAD	TYPICAL GROWTH	1.999	1.241	1.243	4.97	10.90	70	52	3389.89	682.69	NO
R_21_E4B	06-18-19	RAD	TYPICAL GROWTH	1.980	1.236	1.241	4.90	11.06	72	60	3354.19	683.91	NO
R_21_N1D	06-25-19	RAD	TYPICAL GROWTH	2.142	1.113	1.120	4.78	11.31	72	58	3811.04	796.77	NO
R_21_N4H	06-23-19	RAD	TYPICAL GROWTH	1.980	1.235	1.232	4.88	11.04	72	56	3759.77	769.71	NO
R_21_S2A	06-23-19	RAD	PITH GROWTH	1.999	1.246	1.240	4.97	10.98	72	56	4010.01	806.92	NO
R_21_S3G	06-24-19	RAD	TYPICAL GROWTH	2.006	1.246	1.253	5.01	11.39	72	58	3087.46	615.89	NO
R_21_S4H	06-21-19	RAD	TYPICAL GROWTH	1.877	1.245	1.244	4.67	11.44	72	52	3097.84	663.09	NO

TABLE B.10: PARALLEL SHEAR DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFA	LOCATION	WIDTH (in.)	LENGTH (in.)	LENGTH (in.)	SHEAR AREA (in^2)	M.C.% (%)	TEMP (F)	HUMIDI (%)	MAX LOAD (lbs.)	SHEAR STRENG (psi.)	EXCL FLAG
R_21_W4D	06-24-19	RAD	OUTER GROWTH	1.988	1.221	1.220	4.85	9.35	72	58	2746.58	565.99	NO
R_22_N3G	06-24-19	RAD	TYPICAL GROWTH	2.001	1.225	1.223	4.90	10.75	72	58	4526.98	924.17	NO
R_22_S3G	06-24-19	RAD	PITH GROWTH	1.984	1.242	1.236	4.92	11.05	72	58	4450.07	905.16	NO
R_22_S4H	06-25-19	RAD	TYPICAL GROWTH	2.019	1.258	1.267	5.10	9.63	72	58	4278.56	839.27	NO
R_25_N4D	06-25-19	RAD	PITH GROWTH	1.997	1.246	1.242	4.97	11.47	72	58	3699.65	744.62	NO
R_25_S4D	06-24-19	RAD	PITH GROWTH	1.967	1.255	1.264	4.95	10.43	72	58	2783.51	561.77	NO
R_27_N3C	06-25-19	RAD	TYPICAL GROWTH	1.991	1.226	1.227	4.88	11.36	72	58	3771.67	772.26	NO
R_27_N4D	06-23-19	RAD	TYPICAL GROWTH	2.023	1.226	1.225	4.96	10.79	72	56	3906.56	787.87	NO
R_29_E3C	06-25-19	RAD	TYPICAL GROWTH	1.993	1.251	1.245	4.97	11.02	72	58	4436.65	891.87	NO
R_29_N2C	06-21-19	RAD	TYPICAL GROWTH	1.995	1.239	1.243	4.95	11.60	70	54	5073.24	1024.57	NO
R_2_N4D	06-21-19	RAD	TYPICAL GROWTH	1.990	1.218	1.226	4.86	11.42	70	52	3873.60	796.45	NO
R_30_S3C	06-24-19	RAD	TYPICAL GROWTH	1.980	1.221	1.216	4.83	11.64	72	58	3609.92	748.13	NO
R_4_S1D	06-21-19	RAD	PITH GROWTH	2.004	1.237	1.235	4.95	11.41	70	54	3917.85	790.86	NO
R_4_W4D	06-23-19	RAD	OUTER GROWTH	1.972	1.227	1.230	4.85	10.97	72	56	3383.48	698.32	NO
R_5_E3C	06-21-19	RAD	TYPICAL GROWTH	1.982	1.241	1.240	4.92	11.27	70	52	4077.15	829.14	NO
R_5_E4H	06-25-19	RAD	OUTER GROWTH	1.834	1.236	1.237	4.54	11.41	72	58	3900.15	859.92	NO
R_5_N2C	06-23-19	RAD	PITH GROWTH	1.993	1.208	1.201	4.80	11.13	72	56	3951.42	823.02	NO
R_7_S1D	06-25-19	RAD	TYPICAL GROWTH	2.000	1.220	1.223	4.89	11.08	72	58	4618.23	945.20	NO
R_9_N2C	06-21-19	RAD	TYPICAL GROWTH	1.993	1.239	1.245	4.95	11.27	70	45	3040.47	614.16	NO
R_9_W3C	06-18-19	RAD	TYPICAL GROWTH	1.999	1.239	1.232	4.94	11.44	72	60	2947.08	596.63	NO
T_10_E3C	06-18-19	TAN	OUTER GROWTH	1.992	1.263	1.262	5.03	11.74	72	60	5231.02	1040.01	NO
T_10_N4D	06-25-19	TAN	OUTER GROWTH	1.972	1.227	1.225	4.84	10.77	72	58	3160.71	653.67	NO
T_10_S2A	06-23-19	TAN	TYPICAL GROWTH	1.974	1.231	1.230	4.86	10.28	72	56	3439.33	707.97	NO
T_10_S4H	06-21-19	TAN	OUTER GROWTH	1.999	1.249	1.252	5.00	11.03	70	54	4041.14	808.31	NO
T_10_W4D	06-25-19	TAN	OUTER GROWTH	1.832	1.255	1.261	4.61	11.46	72	58	3487.24	756.57	NO
T_11_N3C	06-23-19	TAN	OUTER GROWTH	1.975	1.246	1.242	4.91	10.66	72	56	2778.32	565.41	NO
T_11_N4D	06-18-19	TAN	OUTER GROWTH	1.990	1.254	1.260	5.00	10.52	72	60	3785.40	756.65	NO
T_11_N4I	06-23-19	TAN	TYPICAL GROWTH	1.981	1.226	1.229	4.86	10.17	72	56	4306.03	885.40	NO
T_12_N4H	06-21-19	TAN	OUTER GROWTH	2.003	1.260	1.263	5.05	10.82	70	52	3960.57	783.72	NO
T_12_N4J	06-24-19	TAN	TYPICAL GROWTH	2.011	1.255	1.252	5.04	10.57	72	58	4269.41	846.84	NO
T_12_S3C	06-25-19	TAN	PITH GROWTH	2.001	1.227	1.217	4.89	11.29	72	58	4532.47	926.80	NO
T_12_S3I	06-23-19	TAN	TYPICAL GROWTH	1.994	1.239	1.240	4.94	11.41	72	56	3670.35	742.52	NO
T_12_S4D	06-21-19	TAN	PITH GROWTH	2.000	1.249	1.246	4.99	11.17	70	52	4169.01	835.47	NO
T_13_N3C	06-18-19	TAN	TYPICAL GROWTH	1.990	1.256	1.257	5.00	11.22	72	60	3760.07	751.88	NO
T_13_S3A	06-21-19	TAN	PITH GROWTH	1.936	1.236	1.230	4.77	11.46	70	52	3901.67	817.25	NO
T_15_E3C	06-18-19	TAN	TYPICAL GROWTH	2.002	1.265	1.259	5.05	11.34	72	60	4514.47	893.41	NO

TABLE B.10: PARALLEL SHEAR DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFA	LOCATION	WIDTH (in.)	LENGTH (in.)	LENGTH (in.)	SHEAR AREA (in^2)	M.C.% (%)	TEMP (F)	HUMIDI (%)	MAX LOAD (lbs.)	SHEAR STRENG (psi.)	EXCL FLAG
T_15_E4B	06-24-19	TAN	TYPICAL GROWTH	1.986	1.251	1.249	4.97	11.45	72	58	3815.31	768.44	NO
T_15_N1B	06-24-19	TAN	TYPICAL GROWTH	1.991	1.238	1.245	4.94	9.89	72	58	2866.82	579.90	NO
T_15_N1D	06-25-19	TAN	TYPICAL GROWTH	1.989	1.252	1.250	4.98	11.34	72	58	3740.54	751.64	NO
T_15_N2A	06-23-19	TAN	PITH GROWTH	2.004	1.228	1.229	4.92	10.47	72	56	4138.79	840.56	NO
T_15_N2C	06-18-19	TAN	TYPICAL GROWTH	1.988	1.246	1.248	4.96	11.21	72	62	3961.18	798.94	NO
T_15_S2C	06-21-19	TAN	PITH GROWTH	1.988	1.246	1.254	4.97	11.05	70	52	2940.37	591.62	NO
T_16_N1D	06-25-19	TAN	PITH GROWTH	1.972	1.260	1.264	4.98	11.36	72	58	3740.23	751.45	NO
T_19_N1D	06-24-19	TAN	TYPICAL GROWTH	1.994	1.244	1.244	4.96	10.36	42	58	3489.08	703.29	NO
T_19_S1D	06-18-19	TAN	TYPICAL GROWTH	1.995	1.236	1.240	4.94	11.00	72	60	3895.87	788.70	NO
T_1_W3C	06-24-19	TAN	TYPICAL GROWTH	1.970	1.254	1.258	4.95	10.15	72	58	3481.75	703.58	NO
T_1_W4B	06-23-19	TAN	OUTER GROWTH	1.974	1.239	1.247	4.91	10.32	72	56	3101.20	631.95	NO
T_20_N3K	06-24-19	TAN	TYPICAL GROWTH	1.993	1.233	1.229	4.91	11.57	72	58	4281.92	872.66	NO
T_20_S4J	06-23-19	TAN	TYPICAL GROWTH	2.003	1.241	1.240	4.97	11.15	72	56	4281.62	861.59	NO
T_21_E3C	06-21-19	TAN	TYPICAL GROWTH	1.977	1.263	1.267	5.00	10.90	70	52	3165.28	632.83	NO
T_21_E4B	06-18-19	TNA	TYPICAL GROWTH	1.978	1.265	1.262	5.00	11.10	72	60	3475.34	695.29	NO
T_21_N1D	06-25-19	TAN	TYPICAL GROWTH	2.141	1.140	1.137	4.88	11.34	72	58	3691.10	757.14	NO
T_21_N4H	06-23-19	TAN	TYPICAL GROWTH	1.972	1.208	1.207	4.76	11.17	72	56	2782.59	584.29	NO
T_21_S2A	06-23-19	TAN	PITH GROWTH	1.987	1.216	1.215	4.83	11.01	72	56	3367.92	697.24	NO
T_21_S3G	06-24-19	TAN	TYPICAL GROWTH	1.995	1.239	1.236	4.94	11.22	72	58	3209.84	650.08	NO
T_21_S4H	06-21-19	TAN	TYPICAL GROWTH	1.943	1.256	1.257	4.88	11.41	70	52	3269.04	669.51	NO
T_21_W4D	06-24-19	TAN	OUTER GROWTH	1.983	1.278	1.274	5.06	9.60	72	58	3894.96	769.66	NO
T_22_N3G	06-24-19	TAN	TYPICAL GROWTH	2.004	1.229	1.229	4.93	10.60	72	58	4169.62	846.48	NO
T_22_S3G	06-24-19	TAN	PITH GROWTH	1.996	1.231	1.234	4.92	10.98	72	58	4492.19	913.02	NO
T_22_S4H	06-25-19	TAN	TYPICAL GROWTH	2.002	1.249	1.250	5.00	10.36	72	58	4425.35	884.54	NO
T_25_N4D	06-25-19	TAN	PITH GROWTH	2.010	1.233	1.248	4.99	11.48	72	58	2708.74	543.18	NO
T_25_S4D	06-24-19	TAN	PITH GROWTH	2.012	1.249	1.249	5.03	10.43	72	58	3480.53	692.51	NO
T_27_N3C	06-25-19	TAN	TYPICAL GROWTH	1.982	1.244	1.245	4.93	11.50	72	58	3879.70	786.45	NO
T_27_N4D	06-23-19	TAN	TYPICAL GROWTH	1.984	1.210	1.211	4.80	10.74	72	56	3360.90	699.71	NO
T_29_E3C	06-25-19	TAN	TYPICAL GROWTH	1.981	1.294	1.299	5.14	11.04	72	58	4726.26	920.09	NO
T_29_N2C	06-21-19	TAN	TYPICAL GROWTH	1.999	1.221	1.224	4.89	11.59	70	54	4282.23	876.15	NO
T_2_N4D	06-21-19	TAN	TYPICAL GROWTH	1.997	1.265	1.257	5.04	11.25	70	52	3776.25	749.79	NO
T_30_S3C	06-24-19	TAN	TYPICAL GROWTH	1.999	1.251	1.256	5.01	11.35	72	58	4284.97	855.03	NO
T_4_S1D	06-21-19	TAN	PITH GROWTH	2.007	1.244	1.252	5.01	11.14	70	54	3814.70	761.50	NO
T_4_W4D	06-23-19	TAN	OUTER GROWTH	1.963	1.218	1.217	4.78	11.03	72	56	2915.65	609.98	NO
T_5_E3C	06-21-19	TAN	TYPICAL GROWTH	1.989	1.260	1.266	5.02	11.23	70	52	3779.91	752.34	NO
T_5_E4H	06-25-19	TAN	OUTER GROWTH	1.843	1.217	1.213	4.48	11.19	72	58	3345.64	747.05	NO

TABLE B.10: PARALLEL SHEAR DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFA	LOCATION	WIDTH (in.)	LENGTH (in.)	LENGTH (in.)	SHEAR AREA (in^2)	M.C.% (%)	TEMP (F)	HUMIDI (%)	MAX LOAD (lbs.)	SHEAR STRENG (psi.)	EXCL FLAG
T_5_N2C	06-23-19	TAN	PITH GROWTH	1.970	1.227	1.229	4.84	11.08	72	56	4114.08	850.31	NO
T_7_S1D	06-25-19	TAN	TYPICAL GROWTH	1.977	1.259	1.265	4.99	11.09	72	58	4733.58	948.62	NO
T_9_W3C	06-18-19	TAN	TYPICAL GROWTH	1.984	1.257	1.260	4.99	11.45	72	60	3307.80	662.39	NO
T_9_N2C	06-21-19	TAN	TYPICAL GROWTH	1.975	1.230	1.232	4.86	11.24	70	54	2348.63	483.01	YES

TABLE B.11: PERPENDICULAR TENSION DATA, GREEN WOOD

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	MAX STRESS (PSI.)	EXCL FLAG
R_12_N4C	08-13-19	RAD	GENERAL GROWTH	1.989	1.002	30.69	70	60	564.58	283.28	NO
R_12_N4I	08-13-19	RAD	GENERAL GROWTH	2.002	1.035	31.32	70	60	510.56	246.40	NO
R_12_S4C	08-13-19	RAD	GENERAL GROWTH	1.991	0.981	32.78	70	62	546.26	279.82	NO
R_15_E3D	08-13-19	RAD	PITH GROWTH	2.011	0.936	32.12	70	61	688.02	365.72	NO
R_15_N4A	08-13-19	RAD	GENERAL GROWTH	1.982	0.942	35.60	70	60	487.37	261.04	NO
R_1_E3B	08-13-19	RAD	EXTERIOR GROWTH	2.005	1.000	33.45	70	60	508.58	253.78	NO
R_1_S3H	08-13-19	RAD	EXTERIOR GROWTH	1.995	0.979	77.06	70	60	652.47	334.07	NO
R_1_W4C	08-13-19	RAD	GENERAL GROWTH	2.005	0.955	31.57	70	60	622.86	325.29	NO
R_21_N4A	08-13-19	RAD	GENERAL GROWTH	2.005	1.054	33.26	70	60	432.43	204.63	NO
R_27_N3D	08-13-19	RAD	PITH GROWTH	1.999	0.987	35.54	70	60	546.11	276.93	NO
R_5_S2J	08-13-19	RAD	PITH GROWTH	1.886	0.954	34.11	70	60	410.77	228.42	NO
R_7_N2D	08-13-19	RAD	PITH GROWTH	1.997	0.979	32.35	70	60	495.91	253.65	NO
R_7_W4C	08-13-19	RAD	EXTERIOR GROWTH	2.001	0.970	36.43	70	60	668.95	344.64	NO
T_12_N4C	08-13-19	TAN	GENERAL GROWTH	1.991	0.975	30.98	70	60	864.87	445.76	NO
T_12_N4I	08-13-19	TAN	GENERAL GROWTH	2.005	0.967	31.25	70	60	718.69	370.68	NO
T_12_S4C	08-13-19	TAN	GENERAL GROWTH	1.991	1.040	32.46	70	62	522.77	252.47	NO
T_15_E3D	08-13-19	TAN	PITH GROWTH	2.005	1.003	31.30	72	60	714.26	355.18	NO
T_15_N4A	08-13-19	TAN	GENERAL GROWTH	1.984	0.969	36.54	70	60	712.28	370.50	NO
T_15_S3D	08-13-19	TAN	EXTERIOR GROWTH	1.985	1.029	45.05	70	60	438.23	214.55	NO
T_1_E3B	08-13-19	TAN	EXTERIOR GROWTH	1.942	0.994	34.06	70	60	432.13	223.97	NO
T_1_S3H	08-13-19	TAN	EXTERIOR GROWTH	1.992	1.006	90.40	70	60	672.61	335.64	NO
T_1_W4C	08-13-19	TAN	GENERAL GROWTH	2.004	1.040	31.19	70	60	659.79	316.57	NO
T_21_N4A	08-13-19	TAN	GENERAL GROWTH	2.007	0.994	34.28	70	60	680.08	340.90	NO
T_27_N3D	08-13-19	TAN	PITH GROWTH	1.987	0.973	35.47	70	60	577.24	298.57	NO
T_7_N2D	08-13-19	TAN	PITH GROWTH	2.003	0.995	31.92	70	60	624.69	313.60	NO
T_7_W4C	08-13-19	TAN	EXTERIOR GROWTH	1.996	0.977	35.08	70	60	553.44	283.80	NO

TABLE B.12: PERPENDICULAR TENSION DATA, SEASONED WOOD

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	MAX STRESS (PSI.)	EXCL FLAG
R_10_E3C	06-08-19	RAD	TYPICAL GROWTH	2.001	0.938	10.72	72	48	945.59	503.79	NO
R_10_N4D	06-03-19	RAD	TYPICAL GROWTH	1.997	0.994	11.08	75	45	757.90	382.00	NO
R_10_S1B	06-08-19	RAD	TYPICAL GROWTH	1.998	0.935	9.90	72	48	975.95	522.70	NO
R_10_W3C	06-07-19	RAD	OUTER GROWTH	1.851	0.952	9.90	75	48	702.51	398.88	NO
R_11_N3D	06-07-19	RAD	OUTER GROWTH	1.986	0.938	10.12	75	48	712.43	382.64	NO
R_11_N4D	06-03-19	RAD	OUTER GROWTH	2.002	0.938	10.21	75	45	648.19	345.36	NO
R_11_S1D	06-08-19	RAD	PITH GROWTH	1.880	0.953	10.41	72	48	610.96	341.01	NO
R_11_S3G	06-07-19	RAD	TYPICAL GROWTH	1.981	0.973	10.41	75	48	849.61	440.78	NO
R_11_W3C	06-03-19	RAD	OUTER GROWTH	1.977	0.983	10.22	75	45	777.28	400.17	NO
R_12_N4L	06-07-19	RAD	PITH GROWTH	1.979	0.977	9.79	75	48	592.35	306.52	NO
R_12_S3G	06-04-19	RAD	TYPICAL GROWTH	1.968	0.969	10.00	72	48	670.93	352.01	NO
R_12_S3I	06-04-19	RAD	TYPICAL GROWTH	1.977	1.008	9.84	72	48	744.32	373.50	NO
R_12_S4H	06-04-19	RAD	PITH GROWTH	1.989	0.986	10.24	72	48	574.49	292.94	NO
R_15_E3D	06-04-19	RAD	TYPICAL GROWTH	1.979	0.981	9.87	72	48	816.04	420.55	NO
R_15_N1B	06-07-19	RAD	TYPICAL GROWTH	1.998	0.977	10.32	75	48	823.97	422.11	NO
R_15_N2C	06-07-19	RAD	TYPICAL GROWTH	2.002	0.987	9.84	75	45	457.15	231.47	NO
R_15_S2A	06-04-19	RAD	PITH GROWTH	1.994	0.987	9.75	72	48	755.00	383.82	NO
R_15_S3A	06-04-19	RAD	OUTER GROWTH	1.980	0.998	9.29	72	48	715.48	362.08	NO
R_15_S4B	06-07-19	RAD	OUTER GROWTH	1.976	0.957	9.15	75	45	493.77	261.25	NO
R_15_W4D	06-07-19	RAD	TYPICAL GROWTH	1.974	0.945	9.99	75	48	759.28	407.03	NO
R_16_E3C	06-07-19	RAD	OUTER GROWTH	1.959	0.944	9.09	75	45	893.55	483.19	NO
R_16_N1D	06-07-19	RAD	PITH GROWTH	1.983	0.982	9.72	75	45	632.78	324.95	NO
R_16_S2C	06-07-19	RAD	PITH GROWTH	1.952	0.939	10.06	75	45	707.70	386.31	NO
R_17_S3C	06-04-19	RAD	TYPICAL GROWTH	1.965	0.970	8.68	72	48	787.05	413.13	NO
R_19_S1D	06-03-19	RAD	PITH GROWTH	2.000	0.959	10.86	75	45	746.31	389.31	NO
R_1_E4D	06-07-19	RAD	TYPICAL GROWTH	1.978	0.968	9.33	75	85	718.38	375.19	NO
R_1_N1H	06-07-19	RAD	TYPICAL GROWTH	1.961	0.994	9.45	75	48	358.43	183.97	NO
R_1_S2C	06-08-19	RAD	TYPICAL GROWTH	1.975	0.968	9.89	72	48	1027.83	537.90	NO
R_1_S3A	06-08-19	RAD	OUTER GROWTH	1.998	0.946	10.18	72	48	723.42	382.74	NO
R_1_S4H	06-07-19	RAD	TYPICAL GROWTH	1.996	0.953	10.10	75	48	782.62	411.65	NO
R_1_W4B	06-04-19	RAD	OUTER GROWTH	1.993	0.984	9.51	72	48	541.53	276.28	NO
R_20_N4L	06-08-19	RAD	TYPICAL GROWTH	1.709	0.977	10.10	72	48	766.45	459.27	NO
R_21_N1D	06-08-19	RAD	TYPICAL GROWTH	1.984	0.909	10.17	72	48	733.18	406.77	NO
R_21_N3A	06-03-19	RAD	TYPICAL GROWTH	1.977	0.972	9.48	75	45	739.14	384.84	NO
R_21_N3G	06-07-19	RAD	TYPICAL GROWTH	1.920	0.959	9.72	75	48	690.31	375.10	NO

TABLE B.12: PERPENDICULAR TENSION DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	MAX STRESS (PSI.)	EXCL FLAG
R_21_S1D	06-04-19	RAD	TYPICAL GROWTH	1.983	0.972	9.62	72	48	872.35	452.82	NO
R_22_S4H	06-03-19	RAD	PITH GROWTH	1.995	0.943	10.37	75	45	653.69	347.47	NO
R_23_N3C	06-07-19	RAD	TYPICAL GROWTH	1.968	0.933	9.66	75	48	982.36	535.30	NO
R_23_S4D	06-07-19	RAD	TYPICAL GROWTH	1.966	0.935	9.93	75	48	893.25	485.93	NO
R_25_S4D	06-07-19	RAD	TYPICAL GROWTH	2.008	0.947	9.09	75	45	574.49	302.11	NO
R_28_S4D	06-08-19	RAD	TYPICAL GROWTH	2.011	0.966	10.32	72	48	973.05	501.16	NO
R_29_E3C	06-07-19	RAD	TYPICAL GROWTH	1.985	0.939	8.71	75	45	773.93	415.44	NO
R_29_W3C	06-07-19	RAD	TYPICAL GROWTH	1.995	0.963	10.58	75	48	961.15	500.55	NO
R_30_S3C	06-07-19	RAD	TYPICAL GROWTH	1.984	0.955	10.46	75	45	767.67	405.16	NO
R_4_E4D	06-07-19	RAD	OUTER GROWTH	1.986	0.964	9.81	75	48	875.55	457.32	NO
R_5_E3C	06-08-19	RAD	OUTER GROWTH	1.921	0.946	10.03	72	48	513.15	282.53	NO
R_5_N3C	06-04-19	RAD	OUTHER GROWTH	1.997	0.987	9.34	72	48	534.52	271.18	NO
R_5_S1D	06-07-19	RAD	PITH GROWTH	2.000	0.980	9.65	75	48	997.77	509.33	NO
R_5_S1H	06-04-19	RAD	TYPICAL GROWTH	1.997	0.984	9.52	72	48	921.48	468.93	NO
R_6_S4D	06-08-19	RAD	OUTER GROWTH	1.971	0.945	10.21	72	48	792.24	425.57	NO
R_7_E3C	06-04-19	RAD	TYPICAL GROWTH	1.996	1.017	9.62	72	48	890.96	438.91	NO
R_7_N2C	06-03-19	RAD	TYPICAL GROWTH	1.977	0.953	10.84	75	45	617.83	328.09	NO
R_9_N2C	06-07-19	RAD	PITH GROWTH	1.976	0.939	10.31	75	48	758.82	409.18	NO
T_10_E3C	06-08-19	TAN	TYPICAL GROWTH	1.981	0.928	10.90	72	48	1380.31	751.24	NO
T_10_N4D	06-03-19	TAN	TYPICAL GROWTH	1.998	0.992	11.42	78	45	943.60	476.08	NO
T_10_S1B	06-08-19	TAN	TYPICAL GROWTH	1.976	0.936	10.09	72	48	1007.23	544.88	NO
T_10_W3C	06-07-19	TAN	OUTER GROWTH	1.847	0.968	10.00	75	48	1267.85	709.13	NO
T_11_N3D	06-07-19	TAN	OUTER GROWTH	2.002	0.927	9.99	75	48	905.30	488.07	NO
T_11_N4D	06-03-19	TAN	OUTER GROWTH	1.993	0.970	10.23	75	45	835.72	432.52	NO
T_11_S1D	06-08-19	TAN	PITH GROWTH	1.992	0.972	10.34	72	48	893.10	461.26	NO
T_11_S3G	06-07-19	TAN	TYPICAL GROWTH	1.990	0.959	10.01	75	48	1177.83	617.18	NO
T_11_W3C	06-03-19	TAN	OUTER GROWTH	1.977	0.975	10.33	75	45	1130.37	586.72	NO
T_12_N4L	06-07-19	TAN	PITH GROWTH	1.967	1.015	9.91	75	48	503.85	252.36	NO
T_12_S3G	06-04-19	TAN	TYPICAL GROWTH	1.985	1.008	9.82	72	48	648.04	323.88	NO
T_12_S3I	06-04-19	TAN	TYPICAL GROWTH	1.979	0.989	9.52	72	48	480.50	245.62	NO
T_12_S4H	06-04-19	TAN	PITH GROWTH	1.975	0.987	10.01	72	48	279.54	143.40	NO
T_14_S3C	06-07-19	TAN	TYPICAL GROWTH	1.997	0.957	10.39	75	45	810.85	424.28	NO
T_15_E3D	06-04-19	TAN	TYPICAL GROWTH	1.983	1.009	9.83	72	48	818.02	408.84	NO
T_15_N1B	06-07-19	TAN	TYPICAL GROWTH	1.985	0.973	10.21	75	48	889.89	460.99	NO
T_15_N2C	06-07-19	TAN	TYPICAL GROWTH	2.009	0.992	9.86	75	45	428.31	215.03	NO

TABLE B.12: PERPENDICULAR TENSION DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	MAX STRESS (PSI.)	EXCL FLAG
T_15_S2A	06-04-19	TAN	PITH GROWTH	1.987	1.002	9.80	72	48	663.15	333.08	NO
T_15_S3A	06-04-19	TAN	OUTER GROWTH	1.963	1.000	9.44	72	48	572.05	291.56	NO
T_15_S4B	06-07-19	TAN	OUTER GROWTH	1.943	0.962	9.01	75	45	750.43	401.48	NO
T_15_W4D	06-07-19	TAN	TYPICAL GROWTH	1.963	0.947	9.94	75	48	764.77	411.61	NO
T_16_E3C	06-07-19	TAN	OUTER GROWTH	1.965	0.992	8.86	75	45	865.94	444.23	NO
T_16_N1D	06-07-19	TAN	PITH GROWTH	1.968	0.955	9.67	75	45	883.03	469.83	NO
T_16_S2C	06-07-19	TAN	PITH GROWTH	1.981	0.929	9.96	75	45	785.68	426.92	NO
T_19_S1D	06-03-19	TAN	PITH GROWTH	1.992	0.956	10.79	75	45	685.42	359.93	NO
T_1_E4D	06-07-19	TAN	TYPICAL GROWTH	1.959	0.951	9.42	75	45	908.05	487.41	NO
T_1_N1H	06-07-19	TAN	TYPICAL GROWTH	1.977	1.012	9.31	75	48	598.75	299.27	NO
T_1_S2C	06-08-19	TAN	TYPICAL GROWTH	2.000	0.971	9.93	72	48	808.26	416.20	NO
T_1_S3A	06-08-19	TAN	OUTER GROWTH	1.969	0.945	10.19	72	48	827.79	445.11	NO
T_1_S4H	06-07-19	TAN	TYPICAL GROWTH	1.998	0.935	10.04	75	48	909.73	487.23	NO
T_1_W4B	06-04-19	TAN	OUTER GROWTH	1.985	0.999	9.38	72	48	624.39	315.03	NO
T_20_N4L	06-08-19	TAN	TYPICAL GROWTH	1.994	0.999	10.28	72	48	785.83	394.69	NO
T_21_N1D	06-08-19	TAN	TYPICAL GROWTH	1.989	0.956	10.13	72	48	867.16	456.28	NO
T_21_N3A	06-03-19	TAN	TYPICAL GROWTH	1.971	0.950	9.71	75	45	905.00	483.32	NO
T_21_N3G	06-07-19	TAN	TYPICAL GROWTH	1.915	0.928	9.90	75	48	927.28	522.07	NO
T_21_S1D	06-04-19	TAN	TYPICAL GROWTH	1.958	1.002	9.68	72	48	723.88	368.96	NO
T_22_S4H	06-03-19	TAN	PITH GROWTH	1.978	0.958	9.96	75	45	712.59	376.05	NO
T_23_N3C	06-07-19	TAN	TYPICAL GROWTH	1.966	0.982	9.61	75	48	644.99	334.09	NO
T_23_S4D	06-07-19	TAN	TYPICAL GROWTH	1.969	0.985	9.76	75	48	397.34	204.97	NO
T_25_S4D	06-07-19	TAN	TYPICAL GROWTH	1.996	0.931	10.56	75	45	740.51	398.71	NO
T_28_S4D	06-08-19	TAN	TYPICAL GROWTH	1.998	0.913	10.30	72	48	872.50	478.56	NO
T_29_E3C	06-07-19	TAN	TYPICAL GROWTH	1.970	0.965	8.63	75	45	937.50	493.40	NO
T_29_W3C	06-07-19	TAN	TYPICAL GROWTH	2.003	0.948	10.69	75	48	1246.95	657.03	NO
T_30_S3C	06-07-19	TAN	TYPICAL GROWTH	1.985	0.993	10.11	75	45	887.30	450.15	NO
T_4_E4D	06-07-19	TAN	OUTER GROWTH	1.969	0.914	10.01	75	48	898.44	499.22	NO
T_5_E3C	06-08-19	TAN	OUTER GROWTH	1.917	0.987	9.67	72	48	943.30	498.55	NO
T_5_N3C	06-04-19	TAN	OUTER GROWTH	1.975	0.967	9.37	72	48	1109.62	581.31	NO
T_5_S1D	06-07-19	TAN	PITH GROWTH	1.993	0.977	9.65	75	48	1003.11	515.43	NO
T_5_S1H	06-04-19	TAN	TYPICAL GROWTH	1.982	1.007	9.46	72	48	700.23	350.84	NO
T_5_W4J	06-03-19	TAN	TYPICAL GROWTH	1.954	0.976	10.05	75	45	834.20	437.42	NO
T_6_S4D	06-08-19	TAN	OUTER GROWTH	1.967	0.913	10.22	72	48	938.87	523.08	NO
T_7_E3C	06-04-19	TAN	TYPICAL GROWTH	1.993	1.008	9.82	72	48	1072.08	533.65	NO

TABLE B.12: PERPENDICULAR TENSION DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	MAX STRESS (PSI.)	EXCL FLAG
T_7_N2C	06-03-19	TAN	TYPICAL GROWTH	1.984	1.004	10.69	75	45	646.36	324.49	NO
T_9_N2C	06-07-19	TAN	PITH GROWTH	1.978	0.946	10.28	75	48	1011.20	540.41	NO
R_14_S3C	06-07-19	RAD	TYPICAL GROWTH	1.990	0.957	10.36	75	45	350.49	184.04	YES
R_5_W4J	06-03-19	RAD	TYPICAL GROWTH	1.972	0.976	10.17	75	45	238.49	123.98	YES

TABLE B.13: CLEAVAGE DATA, GREEN WOOD

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	LOAD PER IN. (LBS.)	EXCL FLAG
R_10_N3D	11-05-19	RAD	OUTER GROWTH	1.998	3.036	97.30	74	29	249.02	124.64	NO
R_10_N3D	11-05-19	RAD	OUTER GROWTH	1.998	3.036	97.30	74	29	249.02	124.64	NO
R_10_N4C	11-05-19	RAD	OUTER GROWTH	1.989	2.842	98.24	74	29	256.65	129.04	NO
R_10_N4C	11-05-19	RAD	OUTER GROWTH	1.989	2.842	98.24	74	29	256.65	129.04	NO
R_12_S4I	11-06-19	RAD	PITH GROWTH	1.997	3.040	37.20	74	30	283.66	142.04	NO
R_12_S4I	11-06-19	RAD	PITH GROWTH	1.997	3.040	37.20	74	30	283.66	142.04	NO
R_14_S4C	11-06-19	RAD	TYPICAL GROWTH	2.003	3.047	46.70	74	30	275.88	137.73	NO
R_14_S4C	11-06-19	RAD	TYPICAL GROWTH	2.003	3.047	46.70	74	30	275.88	137.73	NO
R_15_N4A	11-05-19	RAD	TYPICAL GROWTH	2.017	2.997	30.82	74	29	270.54	134.13	NO
R_15_N4A	11-05-19	RAD	TYPICAL GROWTH	2.017	2.997	30.82	74	29	270.54	134.13	NO
R_16_E3D	11-06-19	RAD	OUTER GROWTH	2.005	3.010	69.63	74	30	285.49	142.39	NO
R_16_E3D	11-06-19	RAD	OUTER GROWTH	2.005	3.010	69.63	74	30	285.49	142.39	NO
R_21_E4A	11-06-19	RAD	TYPICAL GROWTH	1.949	3.011	47.63	74	30	266.88	136.93	NO
R_21_E4A	11-06-19	RAD	TYPICAL GROWTH	1.949	3.011	47.63	74	30	266.88	136.93	NO
R_21_E4C	11-06-19	RAD	TYPICAL GROWTH	2.001	3.013	33.42	74	30	272.37	136.12	NO
R_21_E4C	11-06-19	RAD	TYPICAL GROWTH	2.001	3.013	33.42	74	30	272.37	136.12	NO
R_21_N4G	11-05-19	RAD	PITH GROWTH	2.022	2.990	33.32	74	29	276.79	136.89	NO
R_21_N4G	11-05-19	RAD	PITH GROWTH	2.022	2.990	33.32	74	29	276.79	136.89	NO
R_21_S2D	11-05-19	RAD	TYPICAL GROWTH	2.067	2.886	32.56	74	29	303.96	147.05	NO
R_21_S2D	11-05-19	RAD	TYPICAL GROWTH	2.067	2.886	32.56	74	29	303.96	147.05	NO
R_28_S3H	11-05-19	RAD	PITH GROWTH	1.969	3.074	33.86	72	28	314.33	159.64	NO
R_28_S3H	11-05-19	RAD	PITH GROWTH	1.969	3.074	33.86	72	28	314.33	159.64	NO
R_5_N4E	11-06-19	RAD	OUTER GROWTH	1.971	3.026	53.68	74	30	267.79	135.87	NO
R_5_N4E	11-06-19	RAD	OUTER GROWTH	1.971	3.026	53.68	74	30	267.79	135.87	NO
R_5_S1C	11-06-19	RAD	PITH GROWTH	1.974	3.029	31.65	74	30	254.67	129.01	NO
R_5_S1C	11-06-19	RAD	PITH GROWTH	1.974	3.029	31.65	74	30	254.67	129.01	NO
R_6_N3D	11-06-19	RAD	TYPICAL GROWTH	2.008	3.030	33.71	74	30	230.71	114.90	NO
R_6_N3D	11-06-19	RAD	TYPICAL GROWTH	2.008	3.030	33.71	74	30	230.71	114.90	NO
T_10_N3D	11-05-19	TAN	OUTER GROWTH	1.951	3.038	94.43	74	29	285.19	146.17	NO
T_10_N3D	11-05-19	TAN	OUTER GROWTH	1.951	3.038	94.43	74	29	285.19	146.17	NO
T_10_N4C	11-05-19	TAN	OUTER GROWTH	1.989	2.869	92.12	74	29	280.00	140.77	NO
T_10_N4C	11-05-19	TAN	OUTER GROWTH	1.989	2.869	92.12	74	29	280.00	140.77	NO
T_12_S4I	11-06-19	TAN	PITH GROWTH	2.013	3.001	39.34	74	30	277.56	137.88	NO
T_12_S4I	11-06-19	TAN	PITH GROWTH	2.013	3.001	39.34	74	30	277.56	137.88	NO
T_14_S4C	11-06-19	TAN	TYPICAL GROWTH	2.011	3.027	51.02	74	30	298.16	148.26	NO

TABLE B.13: CLEAVAGE DATA, GREEN WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	LOAD PER IN. (LBS.)	EXCL FLAG
T_14_S4C	11-06-19	TAN	TYPICAL GROWTH	2.011	3.027	51.02	74	30	298.16	148.26	NO
T_15_N4A	11-05-19	TAN	TYPICAL GROWTH	2.015	2.960	30.96	74	29	296.48	147.14	NO
T_15_N4A	11-05-19	TAN	TYPICAL GROWTH	2.015	2.960	30.96	74	29	296.48	147.14	NO
T_16_E3D	11-06-19	TAN	OUTER GROWTH	1.913	3.026	72.30	74	30	299.84	156.74	NO
T_16_E3D	11-06-19	TAN	OUTER GROWTH	1.913	3.026	72.30	74	30	299.84	156.74	NO
T_21_E4A	11-06-19	TAN	TYPICAL GROWTH	1.970	3.064	51.66	74	30	259.09	131.52	NO
T_21_E4A	11-06-19	TAN	TYPICAL GROWTH	1.970	3.064	51.66	74	30	259.09	131.52	NO
T_21_E4C	11-06-19	TAN	TYPICAL GROWTH	2.001	3.042	31.95	74	30	297.55	148.70	NO
T_21_E4C	11-06-19	TAN	TYPICAL GROWTH	2.001	3.042	31.95	74	30	297.55	148.70	NO
T_21_N4G	11-05-19	TAN	PITH GROWTH	1.999	3.002	32.51	74	29	283.66	141.90	NO
T_21_N4G	11-05-19	TAN	PITH GROWTH	1.999	3.002	32.51	74	29	283.66	141.90	NO
T_21_S2D	11-05-19	TAN	TYPICAL GROWTH	2.051	2.901	32.69	74	29	300.29	146.41	NO
T_21_S2D	11-05-19	TAN	TYPICAL GROWTH	2.051	2.901	32.69	74	29	300.29	146.41	NO
T_28_S3H	11-05-19	TAN	PITH GROWTH	1.985	2.969	32.63	72	28	326.84	164.66	NO
T_28_S3H	11-05-19	TAN	PITH GROWTH	1.985	2.969	32.63	72	28	326.84	164.66	NO
T_5_N4E	11-06-19	TAN	OUTER GROWTH	1.988	2.971	57.75	74	30	316.01	158.96	NO
T_5_N4E	11-06-19	TAN	OUTER GROWTH	1.988	2.971	57.75	74	30	316.01	158.96	NO
T_5_S1C	11-06-19	TAN	PITH GROWTH	1.984	2.977	31.51	74	30	249.02	125.52	NO
T_5_S1C	11-06-19	TAN	PITH GROWTH	1.984	2.977	31.51	74	30	249.02	125.52	NO
T_6_N3D	11-06-19	TAN	TYPICAL GROWTH	1.999	3.041	33.86	74	30	310.82	155.49	NO
T_6_N3D	11-06-19	TAN	TYPICAL GROWTH	1.999	3.041	33.86	74	30	310.82	155.49	NO
R_28_N3B	11-06-19	RAD	TYPICAL GROWTH	1.991	3.005	32.22	74	30	310.82	156.11	YES
R_28_N3B	11-06-19	RAD	TYPICAL GROWTH	1.991	3.005	32.22	74	30	310.82	156.11	YES
T_28_N3B	11-06-19	TAN	TYPICAL GROWTH	1.983	2.986	33.32	74	30	366.67	184.91	YES
T_28_N3B	11-06-19	TAN	TYPICAL GROWTH	1.983	2.986	33.32	74	30	366.67	184.91	YES

TABLE B.14: CLEAVAGE DATA, SEASONED WOOD

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	LOAD PER IN. (LBS.)	EXCL FLAG
R_10_E4B	06-09-19	RAD	OUTER GROWTH	1.986	2.999	11.83	70	50	500.95	252.24	NO
R_10_N4D	06-10-19	RAD	TYPICAL GROWTH	2.002	2.703	10.78	72	50	574.95	287.19	NO
R_10_W4B	06-10-19	RAD	OUTER GROWTH	1.985	2.884	9.51	72	50	519.56	261.74	NO
R_11_N3C	06-11-19	RAD	OUTER GROWTH	2.103	3.004	10.33	72	52	486.15	231.17	NO
R_11_N3D	06-11-19	RAD	TYPICAL GROWTH	2.000	2.903	10.56	72	52	455.17	227.58	NO
R_11_N4D	06-11-19	RAD	OUTER GROWTH	1.983	2.840	10.58	72	52	484.31	244.23	NO
R_11_N4J	06-11-19	RAD	OUTER GROWTH	1.983	2.734	10.30	72	52	460.21	232.08	NO
R_11_S1D	06-11-19	RAD	TYPICAL GROWTH	2.011	2.926	11.18	72	52	487.21	242.27	NO
R_11_S3I	06-11-19	RAD	TYPICAL GROWTH	1.980	2.746	10.62	72	52	418.85	211.54	NO
R_12_N3C	06-10-19	RAD	TYPICAL GROWTH	1.980	2.249	9.92	72	50	529.79	267.57	NO
R_12_S3I	06-10-19	RAD	TYPICAL GROWTH	1.999	2.731	12.20	72	50	421.60	210.91	NO
R_12_S4H	06-10-19	RAD	PITH GROWTH	1.974	2.722	10.35	72	50	410.92	208.17	NO
R_12_S4J	06-09-19	RAD	PITH GROWTH	1.922	2.990	10.75	70	50	519.71	270.40	NO
R_14_S3C	06-09-19	RAD	TYPICAL GROWTH	1.979	3.008	10.48	72	50	485.69	245.42	NO
R_15_E4B	06-11-19	RAD	TYPICAL GROWTH	1.989	2.752	9.87	72	52	513.15	258.00	NO
R_15_S2A	06-09-19	RAD	TYPICAL GROWTH	1.918	2.949	10.11	70	50	457.76	238.67	NO
R_15_S3A	06-10-19	RAD	OUTER GROWTH	1.986	3.035	10.22	72	50	519.26	261.46	NO
R_15_W3C	06-11-19	RAD	OUTER GROWTH	1.986	2.582	10.63	72	52	459.44	231.34	NO
R_16_E3C	06-09-19	RAD	TYPICAL GROWTH	1.990	2.929	10.02	70	50	507.66	255.11	NO
R_16_N2C	06-11-19	RAD	PITH GROWTH	1.966	2.758	9.86	72	52	485.08	246.73	NO
R_16_W3C	06-10-19	RAD	TYPICAL GROWTH	1.973	2.678	9.95	72	50	474.70	240.60	NO
R_17_N4D	06-11-19	RAD	TYPICAL GROWTH	1.974	2.968	10.93	72	52	455.32	230.66	NO
R_19_S1D	06-11-19	RAD	TYPICAL GROWTH	1.992	3.068	10.64	72	52	414.73	208.20	NO
R_19_S3C	06-11-19	RAD	TYPICAL GROWTH	2.130	2.802	10.51	72	52	503.23	236.26	NO
R_19_W4D	06-09-19	RAD	OUTER GROWTH	1.932	2.761	9.36	70	50	428.31	221.69	NO
R_1_N1H	06-11-19	RAD	TYPICAL GROWTH	1.998	2.531	10.67	72	52	357.21	178.78	NO
R_1_S3C	06-10-19	RAD	OUTER GROWTH	1.988	3.025	11.09	72	50	389.25	195.80	NO
R_20_N4L	06-11-19	RAD	TYPICAL GROWTH	2.003	2.712	10.43	72	52	456.09	227.70	NO
R_20_S2A	06-10-19	RAD	TYPICAL GROWTH	1.977	2.621	11.44	72	50	486.30	245.98	NO
R_21_E4B	06-10-19	RAD	OUTER GROWTH	2.007	2.675	10.69	72	50	403.75	201.17	NO
R_21_N2C	06-09-19	RAD	TYPICAL GROWTH	2.009	2.971	10.48	70	50	486.76	242.29	NO
R_21_S1D	06-10-19	RAD	TYPICAL GROWTH	1.995	2.681	10.44	72	50	418.85	209.95	NO
R_21_S3G	06-09-19	RAD	TYPICAL GROWTH	1.978	3.010	10.62	70	50	412.60	208.59	NO
R_21_S4H	06-10-19	RAD	TYPICAL GROWTH	1.977	2.742	10.18	72	50	445.10	225.14	NO
R_21_W3C	06-10-19	RAD	TYPICAL GROWTH	2.081	2.701	10.14	72	50	470.89	226.28	NO

TABLE B.14: CLEAVAGE DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	LOAD PER IN. (LBS.)	EXCL FLAG
R_21_W4D	06-10-19	RAD	OUTER GROWTH	2.001	2.723	11.08	72	50	432.59	216.19	NO
R_22_N3G	06-10-19	RAD	TYPICAL GROWTH	1.979	2.720	9.89	72	50	534.97	270.33	NO
R_23_S3C	06-09-19	RAD	TYPICAL GROWTH	1.997	2.594	10.50	70	50	468.14	234.42	NO
R_27_N4D	06-10-19	RAD	TYPICAL GROWTH	1.992	2.666	11.18	72	50	455.93	228.88	NO
R_28_N3A	06-09-19	RAD	TYPICAL GROWTH	1.990	2.969	10.31	70	50	578.77	290.84	NO
R_28_N3C	06-11-19	RAD	TYPICAL GROWTH	1.994	2.818	9.85	72	52	531.01	266.30	NO
R_28_N4D	06-11-19	RAD	TYPICAL GROWTH	1.991	2.823	9.85	72	52	509.64	255.97	NO
R_29_S1D	06-09-19	RAD	PITH GROWTH	2.004	2.932	11.10	70	50	496.98	247.99	NO
R_4_S1D	06-11-19	RAD	PITH GROWTH	1.981	2.700	11.64	72	52	479.43	242.01	NO
R_4_W4D	06-10-19	RAD	TYPICAL GROWTH	1.968	2.769	11.07	72	50	443.12	225.16	NO
R_5_E3C	06-09-19	RAD	OUTER GROWTH	1.934	2.815	9.89	70	50	388.95	201.11	NO
R_5_E4D	06-11-19	RAD	OUTER GROWTH	1.991	2.790	11.08	72	52	413.36	207.61	NO
R_5_N2C	06-10-19	RAD	PITH GROWTH	1.999	2.720	10.75	72	50	444.95	222.58	NO
R_5_S1H	06-11-19	RAD	TYPICAL GROWTH	1.994	2.985	11.46	72	52	470.28	235.85	NO
R_5_S2I	06-10-19	RAD	PITH GROWTH	1.986	2.713	10.62	72	50	482.94	243.17	NO
R_5_W4J	06-10-19	RAD	TYPICAL GROWTH	1.961	2.949	10.34	72	50	433.50	221.06	NO
R_7_S1D	06-11-19	RAD	TYPICAL GROWTH	2.010	2.693	10.23	72	52	439.30	218.56	NO
R_9_S1D	06-10-19	RAD	PITH GROWTH	1.992	3.004	10.21	72	50	418.09	209.88	NO
R_9_W3C	06-11-19	RAD	TYPICAL GROWTH	1.980	2.854	10.28	72	52	444.49	224.49	NO
T_10_E4B	06-09-19	TAN	OUTER GROWTH	1.989	2.952	11.59	70	50	561.52	282.31	NO
T_10_N3G	06-10-19	TAN	PITH GROWTH	1.987	2.766	11.54	72	50	565.80	284.75	NO
T_10_N4D	06-10-19	TAN	TYPICAL GROWTH	1.972	2.729	11.01	72	50	522.16	264.78	NO
T_10_W4B	06-10-19	TAN	OUTER GROWTH	1.960	2.972	9.52	72	50	532.99	271.93	NO
T_11_N3C	06-11-19	TAN	OUTER GROWTH	2.057	2.984	10.21	72	52	620.12	301.47	NO
T_11_N3D	06-11-19	TAN	TYPICAL GROWTH	2.003	3.005	10.79	72	52	383.45	191.44	NO
T_11_N4D	06-11-19	TAN	OUTER GROWTH	1.981	2.829	10.48	72	52	466.77	235.62	NO
T_11_N4J	06-11-19	TAN	OUTER GROWTH	1.980	2.728	10.46	72	52	433.35	218.86	NO
T_11_S1D	06-11-19	TAN	TYPICAL GROWTH	1.982	3.044	11.22	72	52	461.12	232.65	NO
T_11_S3I	06-11-19	TAN	TYPICAL GROWTH	1.979	2.738	10.78	72	52	390.63	197.39	NO
T_12_N3C	06-10-19	TAN	TYPICAL GROWTH	1.976	2.730	9.83	72	50	441.89	223.63	NO
T_12_S3I	06-10-19	TAN	TYPICAL GROWTH	1.999	2.715	11.44	72	50	446.01	223.12	NO
T_12_S4H	06-10-19	TAN	PITH GROWTH	1.975	2.807	10.43	72	50	373.54	189.13	NO
T_12_S4J	06-09-19	TAN	PITH GROWTH	1.983	2.891	10.77	70	50	494.08	249.16	NO
T_14_S3C	06-09-19	TAN	TYPICAL GROWTH	1.991	2.916	10.05	72	50	491.64	246.93	NO
T_15_E4B	06-11-19	TAN	TYPICAL GROWTH	1.972	2.786	9.69	72	52	454.56	230.51	NO

TABLE B.14: CLEAVAGE DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	LOAD PER IN. (LBS.)	EXCL FLAG
T_15_S2A	06-09-19	TAN	TYPICAL GROWTH	1.899	2.970	10.17	70	50	436.10	229.65	NO
T_15_S3A	06-10-19	TAN	OUTER GROWTH	1.981	2.951	10.01	72	50	411.53	207.74	NO
T_15_W3C	06-11-19	TAN	OUTER GROWTH	1.985	2.646	10.44	72	52	449.83	226.61	NO
T_16_E3C	06-09-19	TAN	TYPICAL GROWTH	1.975	2.987	9.82	70	50	420.68	213.01	NO
T_16_N2C	06-11-19	TAN	PITH GROWTH	1.959	2.907	9.96	72	52	442.20	225.73	NO
T_16_W3C	06-10-19	TAN	TYPICAL GROWTH	1.970	2.711	9.98	72	50	365.45	185.51	NO
T_17_N4D	06-11-19	TAN	TYPICAL GROWTH	1.978	2.724	11.01	72	52	540.77	273.39	NO
T_19_S1D	06-11-19	TAN	TYPICAL GROWTH	1.990	2.902	10.79	72	52	470.89	236.63	NO
T_19_S3C	06-11-19	TAN	TYPICAL GROWTH	2.128	2.696	10.46	72	52	519.71	244.23	NO
T_19_W4D	06-09-19	TAN	OUTER GROWTH	1.931	2.794	9.62	70	50	478.67	247.89	NO
T_1_N1H	06-11-19	TAN	TYPICAL GROWTH	1.970	2.557	10.55	72	52	484.16	245.77	NO
T_1_S3C	06-10-19	TAN	OUTER GROWTH	1.990	2.918	11.17	72	50	344.85	173.29	NO
T_20_N4L	06-11-19	TAN	TYPICAL GROWTH	2.007	2.752	10.73	72	52	537.11	267.62	NO
T_20_S2A	06-10-19	TAN	TYPICAL GROWTH	1.987	2.807	11.86	72	50	385.13	193.83	NO
T_21_E4B	06-10-19	TAN	OUTER GROWTH	1.972	2.742	10.56	72	50	464.63	235.61	NO
T_21_N2C	06-09-19	TAN	TYPICAL GROWTH	2.011	2.983	10.47	70	50	511.02	254.11	NO
T_21_S1D	06-10-19	TAN	TYPICAL GROWTH	1.961	2.728	10.49	72	50	389.56	198.65	NO
T_21_S3G	06-09-19	TAN	TYPICAL GROWTH	1.991	2.903	10.67	70	50	454.56	228.31	NO
T_21_S4H	06-10-19	TAN	TYPICAL GROWTH	1.966	2.711	10.33	72	50	402.68	204.82	NO
T_21_W3C	06-10-19	TAN	TYPICAL GROWTH	2.061	2.744	9.93	72	50	448.91	217.81	NO
T_21_W4D	06-10-19	TAN	OUTER GROWTH	1.990	2.729	11.26	72	50	438.69	220.45	NO
T_22_N3G	06-10-19	TAN	TYPICAL GROWTH	1.985	2.718	9.92	72	50	509.03	256.44	NO
T_23_S3C	06-09-19	TAN	TYPICAL GROWTH	1.987	2.676	10.45	70	50	437.32	220.09	NO
T_27_N4D	06-10-19	TAN	TYPICAL GROWTH	2.049	2.767	11.48	72	50	457.76	223.41	NO
T_28_N3A	06-09-19	TAN	TYPICAL GROWTH	1.991	2.948	10.41	70	50	591.13	296.90	NO
T_28_N3C	06-11-19	TAN	TYPICAL GROWTH	1.972	2.989	10.04	72	52	523.07	265.25	NO
T_28_N4D	06-11-19	TAN	TYPICAL GROWTH	1.983	2.868	9.84	72	52	353.39	178.21	NO
T_29_S1D	06-09-19	TAN	PITH GROWTH	2.004	2.980	11.15	70	50	460.97	230.02	NO
T_4_S1D	06-11-19	TAN	PITH GROWTH	1.985	2.786	11.67	72	52	513.31	258.59	NO
T_4_W4D	06-10-19	TAN	TYPICAL GROWTH	1.977	2.767	11.12	72	50	503.39	254.62	NO
T_5_E3C	06-09-19	TAN	OUTER GROWTH	1.896	2.848	10.11	70	50	475.62	250.85	NO
T_5_E4D	06-11-19	TAN	OUTER GROWTH	1.969	2.654	11.02	72	52	488.59	248.14	NO
T_5_N2C	06-10-19	TAN	PITH GROWTH	1.984	2.682	10.70	72	50	464.33	234.03	NO
T_5_N4D	06-10-19	TAN	OUTER GROWTH	1.977	2.689	10.20	72	50	574.34	290.51	NO
T_5_S1H	06-11-19	TAN	TYPICAL GROWTH	1.989	2.916	11.23	72	52	491.33	247.03	NO

TABLE B.14: CLEAVAGE DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	SURFAC	LOCATION	WIDTH (in.)	LENGTH (in.)	M.C.% (%)	TEMP (F)	HUMIDITY (%)	MAX LOAD (lbs.)	LOAD PER IN. (LBS.)	EXCL FLAG
T_5_S2I	06-10-19	TAN	PITH GROWTH	1.967	2.731	10.59	72	50	346.07	175.94	NO
T_5_W4J	06-10-19	TAN	TYPICAL GROWTH	1.984	2.805	10.37	72	50	476.68	240.26	NO
T_7_S1D	06-11-19	TAN	TYPICAL GROWTH	2.001	2.832	10.31	72	52	513.92	256.83	NO
T_9_S1D	06-10-19	TAN	PITH GROWTH	1.992	2.759	10.05	72	50	414.12	207.89	NO
T_9_W3C	06-11-19	TAN	TYPICAL GROWTH	1.977	2.944	10.73	72	52	437.16	221.13	NO
R_10_N3G	06-10-19	RAD	PITH GROWTH	1.990	2.748	11.84	72	50	657.81	330.56	YES
R_20_N3K	06-10-19	RAD	PITH GROWTH NO	1.984	2.687	11.25	72	50	384.52	193.81	YES
R_5_N4D	06-10-19	RAD	OUTER GROWTH	1.977	2.723	10.26	72	50	270.69	136.92	YES
T_20_N3K	06-10-19	TAN	PITH GROWTH NO	1.971	2.788	11.02	72	50	360.41	182.86	YES

TABLE B.15: HARDESS DATA, GREEN WOOD

SAMPLE NUMBER	DATE	HEIGHT (in.)	WIDTH (in.)	LENGTH (in.)	WEIGHT (gm.)	M.C.% (%)	RINGS (/in.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMIDI (%)	IMPRESSION LOADS AVG RAD (lbs.)	AVG TAN (lbs.)	AVG END (lbs.)	RAD AND TAN AVG (lbs.)	EXCL FLAG
1_10_E4C	01-15-19	1.952	1.948	4.340	174.6	69.81	30	75	15	72	32	301.13	320.97	371.02	311.05	NO
1_10_N1A	01-18-19	2.001	2.015	4.036	139.9	36.26	30	0	15	70	30	330.58	339.58	429.76	335.08	NO
1_10_N4E	01-14-19	2.016	2.005	4.147	152.7	33.29	32	0	15	74	34	458.07	437.32	420.15	447.69	NO
1_10_S2B	01-18-19	2.016	2.132	5.483	201.4	36.19	26	0	10	70	30	378.19	387.88	380.78	383.03	NO
1_10_W3D	01-25-19	2.040	2.036	5.774	218.8	43.77	28	30	15	75	20	388.03	325.39	442.35	356.71	NO
1_11_E4C	01-14-19	2.002	2.006	5.961	214.8	40.42	26	15	10	74	34	293.88	265.58	304.72	279.73	NO
1_11_S1C	01-13-19	1.822	1.915	5.822	160.0	33.42	26	0	10	75	32	330.89	285.80	330.58	308.34	NO
1_11_W3D	01-13-19	2.002	2.001	5.017	159.3	33.51	32	0	10	75	32	327.22	273.21	313.11	300.22	NO
1_12_N3L	01-14-19	2.002	2.008	4.442	164.8	47.69	20	15	15	74	34	324.63	353.55	328.14	339.09	NO
1_12_S4K	01-14-19	2.000	2.002	4.587	155.9	36.16	22	0	15	72	34	324.71	308.08	378.72	316.39	NO
1_14_N3D	01-18-19	2.014	2.015	5.650	190.8	44.99	26	5	10	70	29	311.66	309.14	327.53	310.40	NO
1_14_S4C	01-18-19	2.017	2.016	4.341	165.8	66.63	30	50	10	70	30	234.91	255.28	308.99	245.09	NO
1_15_N4A	01-14-19	1.996	1.969	5.563	167.2	30.61	22	0	20	72	34	289.38	286.03	367.05	287.70	NO
1_15_S1A	01-18-19	2.021	2.017	4.732	154.7	37.14	22	0	7	70	30	298.61	314.64	333.33	306.63	NO
1_16_E3D	01-13-19	1.928	2.013	5.569	225.2	67.74	22	40	15	75	32	275.12	286.18	310.75	280.65	NO
1_16_W4C	01-15-19	2.002	2.009	5.991	261.8	63.02	26	80	15	72	32	289.99	306.78	294.11	298.39	NO
1_17_N3D	01-15-19	2.015	2.017	5.587	209.4	33.92	32	5	15	72	32	351.56	380.17	420.30	365.87	NO
1_17_N4C	01-25-19	2.005	2.019	5.585	204.3	33.20	25	5	15	75	20	360.57	360.34	433.88	360.45	NO
1_17_W3D	01-25-19	1.911	1.910	5.450	254.3	94.02	18	75	10	75	20	317.23	309.45	325.09	313.34	NO
1_19_S4C	01-25-19	2.030	2.028	5.754	216.0	33.27	30	0	15	75	20	418.24	444.11	406.11	431.18	NO
1_19_W1L	01-14-19	1.959	2.007	5.945	195.0	40.18	26	0	15	72	34	328.90	361.79	335.08	345.34	NO
1_1_E4C	01-14-19	2.010	2.007	4.375	155.2	30.91	46	0	20	72	34	403.06	503.46	402.91	453.26	NO
1_1_N2D	01-18-19	2.012	2.002	3.620	129.7	41.91	24	0	15	70	30	274.73	312.88	363.24	293.81	NO
1_1_S3H	01-18-19	2.017	2.002	4.459	168.0	44.76	24	5	10	70	29	303.96	307.24	334.24	305.60	NO
1_1_S4C	01-18-19	2.019	1.992	4.403	158.2	38.18	20	10	20	70	30	297.32	409.85	357.36	353.58	NO
1_1_W3B	01-15-19	1.984	1.996	4.426	149.3	30.03	20	0	25	72	32	346.37	311.97	415.19	329.17	NO
1_20_N3C	01-18-19	2.011	2.013	4.081	135.0	34.09	16	0	10	70	30	320.05	332.03	361.10	326.04	NO
1_20_N3L	01-14-19	1.995	2.004	5.769	190.5	33.45	16	0	15	74	34	314.56	300.67	334.24	307.62	NO
1_20_N4A	01-14-19	1.998	2.003	5.700	193.3	55.19	18	45	20	72	34	228.35	209.12	347.44	218.73	NO
1_20_N4K	01-14-19	2.004	1.995	4.005	137.1	35.25	18	0	15	72	34	276.95	379.79	373.76	328.37	NO
1_20_S3L	01-13-19	2.038	2.030	5.800	192.7	34.27	16	0	15	75	32	311.20	282.82	326.16	297.01	NO
1_20_S4I	01-13-19	2.011	1.901	6.058	206.0	36.58	18	0	20	75	32	401.38	401.84	378.11	401.61	NO
1_21_E4C	01-18-19	2.015	2.001	4.629	206.7	99.41	22	65	15	70	30	246.12	209.88	284.04	228.00	NO
1_21_N1C	01-13-19	1.994	2.001	5.113	159.5	33.08	22	0	15	75	32	322.11	302.28	330.81	312.19	NO
1_21_N3H	01-18-19	2.002	2.004	5.050	161.2	33.59	24	0	10	70	30	306.63	316.77	347.06	311.70	NO
1_21_N4C	01-25-19	1.909	1.918	6.125	237.2	57.20	26	40	10	75	20	304.34	287.02	335.01	295.68	NO

TABLE B.15: HARDESS DATA, GREEN WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (in.)	WIDTH (in.)	LENGTH (in.)	WEIGHT (gm.)	M.C.% (%)	RINGS (/in.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMIDI (%)	IMPRESSION LOADS AVG RAD (lbs.)	AVG TAN (lbs.)	AVG END (lbs.)	RAD AND TAN AVG (lbs.)	EXCL FLAG
1_21_N4G	01-15-19	2.049	2.046	3.977	133.4	35.51	25	0	15	72	32	263.52	328.90	339.66	296.21	NO
1_21_S2B	01-14-19	2.000	2.003	4.761	154.6	34.71	30	0	10	72	34	285.57	289.61	352.02	287.59	NO
1_22_S4G	01-13-19	1.992	1.976	5.965	195.0	30.82	26	0	15	75	32	373.38	356.14	376.21	364.76	NO
1_23_N3D	01-14-19	2.005	1.993	5.046	177.7	36.45	30	0	15	72	34	379.94	401.76	369.11	390.85	NO
1_23_S3D	01-18-19	2.000	2.010	5.778	109.9	38.35	38	5	10	70	30	328.90	319.75	374.37	324.33	NO
1_25_N3D	01-15-19	2.006	2.000	5.216	171.4	35.57	38	0	20	72	32	289.99	278.09	319.67	284.04	NO
1_25_S3D	01-18-19	2.013	2.003	3.978	144.6	59.50	35	50	7	70	30	215.23	239.03	343.25	227.13	NO
1_27_N3D	01-14-19	1.999	2.002	5.036	173.7	37.82	30	0	15	74	34	322.04	341.57	364.76	331.80	NO
1_28_N3B	01-18-19	2.004	2.012	5.889	196.3	33.63	26	0	10	70	30	313.42	344.16	382.61	328.79	NO
1_28_S3H	01-14-19	1.992	1.993	4.243	143.4	36.24	30	0	15	74	34	320.89	321.12	355.15	321.01	NO
1_29_N1C	01-25-19	2.011	2.023	5.373	194.0	39.81	32	0	15	75	20	415.19	357.82	373.69	386.51	NO
1_29_W3D	01-25-19	2.042	2.027	5.346	187.4	32.79	32	5	15	75	20	315.25	415.95	397.95	365.60	NO
1_2_N3D	01-14-19	1.997	2.001	5.107	175.9	34.23	40	5	10	72	34	328.83	334.47	362.93	331.65	NO
1_2_N4C	01-14-19	1.987	1.992	4.611	151.9	32.52	34	0	10	72	34	276.34	315.02	348.82	295.68	NO
1_4_N2C	01-13-19	1.996	2.021	5.749	184.3	33.70	38	0	15	75	32	316.09	331.34	395.13	323.72	NO
1_4_S2D	01-18-19	2.013	2.012	4.141	168.2	46.43	28	10	10	70	30	332.95	324.25	375.29	328.60	NO
1_4_W3D	01-25-19	2.028	2.015	5.952	193.8	33.61	24	10	10	75	20	317.23	312.12	401.99	314.67	NO
1_5_N1I	01-15-19	1.984	2.001	4.396	139.9	33.66	22	0	10	72	32	329.21	314.48	346.53	321.85	NO
1_5_N2D	01-25-19	2.024	2.019	5.857	183.8	33.33	26	0	10	75	20	295.49	293.27	353.47	294.38	NO
1_5_S1C	01-15-19	1.943	1.985	3.871	112.5	32.05	26	0	15	72	32	300.37	306.55	304.18	303.46	NO
1_5_S1G	01-13-19	2.010	2.010	5.690	186.6	34.71	16	0	15	75	32	263.67	289.99	283.36	276.83	NO
1_5_W3D	01-18-19	2.007	2.007	4.850	182.1	70.16	24	45	15	70	30	146.10	264.36	283.89	205.23	NO
1_5_W4C	01-14-19	1.985	1.973	5.174	163.8	33.89	20	5	15	72	34	322.95	329.90	403.44	326.42	NO
1_6_S3D	01-25-19	2.016	2.019	5.424	176.9	33.78	22	0	10	75	20	300.45	340.73	341.03	320.59	NO
1_20_N1C	01-14-19	1.955	1.978	4.139	129.9	38.73	22	0	15	72	34	214.00	246.51	367.05	230.26	YES
1_20_S4C	01-13-19	2.026	2.020	5.488	194.2	44.19	18	10	20	75	32	282.06	328.37	367.05	305.21	YES

TABLE B.16: HARDESS DATA, SEASONED WOOD

SAMPLE NUMBER	DATE	HEIGHT (in.)	WIDTH (in.)	LENGTH (in.)	WEIGHT (gm.)	M.C.% (%)	RINGS (/in.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMIDI (%)	IMPRESSION LOADS AVG RAD (lbs.)	AVG TAN (lbs.)	AVG END (lbs.)	RAD AND TAN AVG (lbs.)	EXCL FLAG
1_10_W4D	06-29-19	1.849	1.835	4.390	116.7	11.59	24	0	15	72	52	529.94	522.54	590.90	526.24	NO
1_11_N3C	07-01-19	1.993	1.993	4.466	125.1	11.51	32	15	10	72	62	435.18	537.87	545.35	486.53	NO
1_11_N4D	06-28-19	2.009	2.006	4.961	138.8	10.39	34	0	15	72	58	439.22	474.47	466.31	456.85	NO
1_11_N4J	07-01-19	1.880	1.883	4.492	118.1	12.10	20	20	10	72	62	430.98	433.58	668.95	432.28	NO
1_11_S2C	06-28-19	1.999	2.008	5.030	145.6	10.73	28	0	15	72	58	540.85	499.65	516.66	520.25	NO
1_11_W3C	06-28-19	1.989	1.981	4.315	121.6	11.64	30	0	15	72	58	486.22	421.22	512.92	453.72	NO
1_12_N3K	06-28-19	1.982	1.993	5.422	156.5	11.67	24	0	15	72	58	492.02	440.75	532.68	466.38	NO
1_12_N4D	06-29-19	2.012	2.009	4.941	178.0	11.01	22	0	20	72	52	534.36	620.42	610.96	577.39	NO
1_12_N4H	06-29-19	1.998	1.999	5.826	185.0	11.11	24	0	15	72	52	473.40	507.97	568.77	490.68	NO
1_12_N4J	06-29-19	2.002	2.007	4.782	148.0	11.12	11	0	15	72	52	449.83	518.49	617.45	484.16	NO
1_12_S3C	06-29-19	1.996	2.004	5.028	161.3	11.39	30	0	15	72	52	596.31	567.17	553.89	581.74	NO
1_12_S3K	07-01-19	2.008	2.007	4.179	133.2	12.18	18	0	10	72	62	446.70	462.49	569.08	454.60	NO
1_12_S4D	06-28-19	1.984	1.995	5.139	165.0	11.03	32	0	15	72	58	584.49	539.55	685.27	562.02	NO
1_13_S3A	06-29-19	1.922	1.938	4.319	129.5	11.38	45	0	15	72	52	618.90	549.09	558.70	583.99	NO
1_15_E3C	06-28-19	1.999	2.008	4.031	123.1	10.91	20	0	15	72	58	460.51	567.17	618.97	513.84	NO
1_15_N1B	06-28-19	1.928	2.000	5.172	138.6	10.92	22	0	15	72	58	434.65	449.22	499.34	441.93	NO
1_15_N2A	06-28-19	2.015	2.006	5.351	156.6	11.13	22	0	15	72	58	429.69	394.90	491.18	412.29	NO
1_15_N2C	06-28-19	2.010	2.011	4.710	143.3	10.96	26	0	15	72	58	429.84	458.22	520.17	444.03	NO
1_15_S3A	06-28-19	1.981	1.968	4.098	111.5	9.79	28	15	15	72	58	400.85	551.61	535.58	476.23	NO
1_16_S2C	07-01-19	1.966	1.973	5.401	152.9	10.55	22	0	10	72	62	452.96	501.18	593.34	477.07	NO
1_17_S3C	06-28-19	1.993	1.990	4.988	163.9	11.29	45	0	15	72	58	517.20	577.39	555.57	547.29	NO
1_19_N1D	06-29-19	1.999	1.995	5.006	142.2	10.62	28	0	10	72	52	470.43	495.00	527.04	482.71	NO
1_1_N1B	06-29-19	1.996	1.989	5.237	145.1	11.38	18	0	10	72	52	432.28	483.09	528.95	457.69	NO
1_1_W3C	06-28-19	1.999	1.985	5.098	148.3	11.36	26	0	15	72	58	450.13	392.46	521.77	421.30	NO
1_1_W4A	07-01-19	1.994	1.980	4.003	117.8	10.03	28	10	10	75	62	511.78	543.59	678.56	527.69	NO
1_1_W4B	06-28-19	1.967	1.975	4.863	139.4	10.06	36	0	10	72	58	497.28	471.34	516.13	484.31	NO
1_1_W5A	06-28-19	2.006	1.989	4.023	130.7	10.46	16	0	20	72	58	643.46	542.37	631.87	592.92	NO
1_20_N3K	06-28-19	1.986	2.001	3.935	111.3	11.71	18	0	15	72	58	464.48	390.47	511.63	427.48	NO
1_20_S3C	06-28-19	1.991	1.985	5.002	146.1	10.61	22	15	15	72	58	489.27	526.28	652.47	507.77	NO
1_21_E4B	06-28-19	2.003	1.984	5.789	160.9	10.84	28	10	10	72	58	457.46	463.18	508.88	460.32	NO
1_21_N4H	06-28-19	1.984	1.985	4.405	125.9	11.37	22	0	10	72	58	467.68	426.03	594.25	446.85	NO
1_21_S3G	06-29-19	2.004	1.993	4.906	139.8	11.64	26	0	10	72	52	397.03	389.86	549.16	393.45	NO
1_21_S4H	06-28-19	1.891	1.942	5.692	147.7	11.16	26	0	10	72	58	440.60	484.92	523.61	462.76	NO
1_21_W4D	07-01-19	2.001	1.992	4.922	139.1	11.08	20	15	15	72	62	407.87	491.03	534.06	449.45	NO
1_22_N3G	06-29-19	1.997	1.994	5.003	152.9	11.33	24	0	15	72	52	547.64	515.67	640.56	531.65	NO
1_22_S3G	06-29-19	1.995	1.990	4.943	150.6	11.19	26	0	15	72	52	488.59	494.23	599.90	491.41	NO

TABLE B.16: HARDESS DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (in.)	WIDTH (in.)	LENGTH (in.)	WEIGHT (gm.)	M.C.% (%)	RINGS (/in.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMIDI (%)	IMPRESSION LOADS AVG RAD (lbs.)	AVG TAN (lbs.)	AVG END (lbs.)	RAD AND TAN AVG (lbs.)	EXCL FLAG
1_22_S4H	06-29-19	2.002	2.014	4.407	132.9	10.63	20	0	15	72	52	486.83	527.57	671.16	507.20	NO
1_25_S4D	06-29-19	1.988	1.999	5.188	141.5	10.93	38	0	10	72	52	376.13	419.31	568.77	397.72	NO
1_27_N3C	06-29-19	2.005	1.991	4.504	138.6	11.21	30	0	10	72	52	491.56	533.14	540.31	512.35	NO
1_29_N2C	06-29-19	1.991	1.987	5.976	190.3	11.40	36	0	15	72	52	549.55	462.34	590.90	505.94	NO
1_29_S3C	07-01-19	2.005	2.002	5.214	153.8	10.14	48	10	10	72	62	498.58	510.10	649.64	504.34	NO
1_2_N4D	06-29-19	1.985	1.990	5.104	152.3	11.19	28	0	15	72	52	419.46	441.67	527.34	430.56	NO
1_2_S3C	07-01-19	1.997	2.011	5.030	146.3	10.65	38	5	10	72	62	479.74	421.37	506.74	450.55	NO
1_30_S3C	06-29-19	1.982	1.987	4.960	150.7	11.96	38	15	15	72	52	511.09	558.55	579.99	534.82	NO
1_4_S1D	06-28-19	1.996	1.993	4.697	134.1	11.12	34	0	10	72	58	457.31	484.16	552.06	470.73	NO
1_4_W4D	06-29-19	1.987	1.986	4.892	132.9	11.31	24	30	15	72	52	417.86	450.52	569.53	434.19	NO
1_5_E4H	06-29-19	1.832	1.835	5.460	133.8	11.48	20	35	15	72	52	455.09	403.44	567.47	429.27	NO
1_5_E4J	06-29-19	1.953	2.002	4.917	139.9	11.81	20	75	15	72	52	426.03	411.00	543.29	418.51	NO
1_5_N2C	06-28-19	1.999	1.994	4.732	128.5	11.32	22	0	10	72	58	487.29	408.71	502.62	448.00	NO
1_5_N4D	06-29-19	1.997	1.987	4.966	154.7	11.37	26	20	10	72	52	438.39	477.37	533.14	457.88	NO
1_5_S1D	06-29-19	1.983	1.986	5.279	146.7	11.57	28	0	10	72	52	465.47	484.85	531.54	475.16	NO
1_5_W3C	07-01-19	1.987	1.985	5.271	161.0	10.16	32	0	10	72	62	548.02	579.22	669.02	563.62	NO
1_7_S1D	06-29-19	1.990	2.006	4.998	158.6	11.06	28	0	15	72	52	545.96	502.24	556.26	524.10	NO
1_1_S3L	06-28-19	1.716	2.003	5.731	139.0	12.03	22	20	15	72	58	232.93	438.16	482.25	335.54	YES
1_27_N4D	06-29-19	2.034	2.001	4.435	133.5	11.21	26	0	10	72	52	840.07	547.64	523.99	693.86	YES

TABLE B.17: NAIL WITHDRAWAL DATA, GREEN WOOD

SAMPLE NUMBER	DATE	HEIGHT (in.)	WIDTH (in.)	LENGTH (in.)	WEIGHT (gm.)	M.C.% (%)	RINGS (/in.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMIDI (%)	EXTRACTION FORCE AVG RAD (lbs.)	EXTRACTION FORCE AVG TAN (lbs.)	EXTRACTION FORCE AVG END (lbs.)	SPECIFIC GRAVITY	EXCL FLAG
1_5_W3J	01-28-19	2.003	2.014	5.831	181.0	34.29	16	0	7	75	25	87.45	91.41	47.08	0.35	NO
1_5_S1C	01-28-19	2.010	2.000	5.370	165.8	35.21	22	0	10	75	25	93.22	84.75	43.79	0.35	NO
1_2_N3D	01-29-19	1.994	2.002	4.053	140.8	37.53	34	0	10	75	25	109.41	112.94	50.10	0.39	NO
1_29_N1C	01-29-19	2.006	2.025	6.023	236.0	38.20	28	0	18	75	25	151.05	133.11	76.71	0.43	NO
1_25_S3D	01-28-19	2.001	2.012	5.902	211.6	57.59	32	30	10	75	25	90.03	89.28	46.92	0.34	NO
1_25_N3D	01-28-19	2.006	2.001	6.032	190.6	35.53	36	0	10	75	25	107.69	108.32	54.23	0.35	NO
1_21_S2D	01-29-19	2.060	2.060	5.610	196.1	32.16	26	0	10	75	25	106.95	109.33	48.25	0.38	NO
1_21_N4C	01-28-19	2.025	2.015	5.970	240.4	68.59	20	60	10	75	25	103.67	104.92	45.12	0.36	NO
1_20_S4I	01-29-19	1.904	2.022	3.718	119.2	33.74	16	0	15	75	25	96.92	112.11	60.46	0.38	NO
1_20_N3C	01-28-19	2.006	2.012	5.914	195.7	34.62	18	0	15	75	25	104.79	127.56	48.95	0.37	NO
1_1_W3B	01-29-19	2.015	2.020	4.156	144.1	30.51	18	0	20	75	25	119.73	139.27	52.20	0.40	NO
1_1_S3H	01-29-19	2.016	2.011	4.244	140.8	36.98	22	0	10	75	25	103.09	97.37	50.45	0.36	NO
1_19_W3D	01-28-19	2.006	2.018	5.893	287.4	108.86	20	90	15	75	25	76.32	105.52	39.76	0.35	NO
1_15_S4A	01-29-19	2.015	2.015	4.185	157.8	76.43	22	35	10	75	25	106.38	100.19	41.04	0.32	NO
1_12_N3L	01-29-19	2.017	2.003	5.433	201.6	40.36	18	0	10	75	25	103.72	121.04	48.72	0.40	NO
1_10_N1A	01-28-19	2.007	2.007	5.778	205.9	33.98	28	0	10	75	25	151.48	141.54	70.06	0.40	NO

TABLE B.18: NAIL WITHDRAWAL DATA, SEASONED WOOD

SAMPLE NUMBER	DATE	HEIGHT (in.)	WIDTH (in.)	LENGTH (in.)	WEIGHT (gm.)	M.C.% (%)	RINGS (/in.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMIDI (%)	EXTRACTION FORCE AVG RAD (lbs.)	AVG TAN (lbs.)	AVG END (lbs.)	SPECIFIC GRAVITY	EXCL FLAG
1_10_E3C	07-06-19	1.983	1.988	5.559	177.3	10.88	26	20	15	75	52	96.95	125.65	59.84	0.45	NO
1_10_N4D	07-07-19	1.985	1.983	5.629	153.7	11.49	24	10	10	75	52	83.53	71.72	46.36	0.38	NO
1_10_S2C	07-05-19	1.993	2.002	5.948	177.8	10.47	20	0	10	72	52	77.58	100.41	62.65	0.41	NO
1_11_N3C	07-05-19	1.984	1.994	4.312	121.1	10.78	28	10	15	72	52	91.03	77.74	29.45	0.39	NO
1_11_N4J	07-06-19	1.880	1.881	4.130	108.0	11.05	24	15	15	75	52	126.26	116.35	78.60	0.41	NO
1_11_S1D	07-07-19	1.878	1.984	5.649	152.1	10.47	28	0	15	75	52	88.41	66.35	47.03	0.40	NO
1_12_N3C	07-06-19	1.986	1.992	4.431	150.0	11.21	12	0	20	75	52	143.27	143.01	76.20	0.47	NO
1_12_N3K	07-02-19	1.987	1.975	4.940	147.8	11.79	24	0	15	75	55	86.39	77.87	42.30	0.42	NO
1_12_N4D	07-02-19	2.005	2.000	3.827	129.2	11.67	28	0	15	75	55	84.70	88.43	41.64	0.46	NO
1_12_N4J	07-05-19	2.012	2.006	4.701	144.3	11.89	24	0	15	72	52	71.04	76.35	56.98	0.41	NO
1_12_S3K	07-05-19	2.011	2.012	4.716	136.8	11.26	24	0	15	72	52	62.00	75.17	61.26	0.39	NO
1_13_S3A	07-05-19	1.932	1.922	5.781	178.1	11.60	48	0	15	72	52	138.50	82.83	72.53	0.45	NO
1_15_N1B	07-05-19	1.932	2.014	5.653	158.6	10.97	26	0	10	72	52	76.29	82.32	36.82	0.40	NO
1_15_N4B	07-06-19	2.007	1.988	5.668	163.8	11.31	22	5	15	75	52	75.10	77.35	51.83	0.40	NO
1_15_S2C	07-06-19	2.008	1.990	4.425	126.7	10.53	20	0	10	75	52	68.72	99.75	37.13	0.40	NO
1_16_E4D	07-07-19	1.977	1.983	5.653	166.5	11.26	22	10	15	77	52	79.20	79.10	61.63	0.41	NO
1_16_S2C	07-05-19	1.995	1.968	4.010	118.5	11.51	28	0	10	72	52	79.74	82.76	52.15	0.41	NO
1_16_W3C	07-02-19	1.981	1.980	4.806	139.8	12.05	26	20	10	75	55	103.83	98.43	48.15	0.40	NO
1_17_S4D	07-07-19	1.982	2.005	5.625	183.5	10.97	28	0	15	75	52	144.26	100.58	55.18	0.45	NO
1_19_N1D	07-06-19	2.011	2.004	5.497	157.9	9.82	30	0	10	75	52	84.39	69.86	45.24	0.40	NO
1_19_S2C	07-06-19	2.001	1.992	5.418	160.9	11.52	24	0	10	75	52	118.55	83.02	54.96	0.41	NO
1_1_E4B	07-06-19	1.840	1.966	5.538	140.1	10.58	20	20	10	75	52	54.26	74.64	30.50	0.39	NO
1_1_S3A	07-05-19	1.996	1.987	3.634	100.9	11.86	18	40	10	72	52	75.69	95.88	48.07	0.38	NO
1_1_W3C	07-05-19	2.011	1.998	4.260	127.3	11.59	26	0	15	72	52	76.75	63.64	35.15	0.41	NO
1_1_W4H	07-06-19	1.813	2.002	5.791	151.4	11.66	18	0	15	75	52	73.01	64.73	47.80	0.39	NO
1_1_W5A	07-05-19	1.997	1.998	4.496	143.9	10.93	22	0	20	72	52	140.33	106.15	64.76	0.44	NO
1_20_N3K	07-02-19	2.015	2.007	3.683	105.8	11.83	20	10	10	75	55	65.06	116.61	49.43	0.39	NO
1_20_S1B	07-06-19	1.993	2.004	4.957	133.4	10.45	26	0	10	75	52	117.47	106.54	67.57	0.37	NO
1_21_E4D	07-07-19	1.976	1.991	5.635	156.9	10.91	32	30	15	75	52	70.84	78.59	34.49	0.39	NO
1_21_N4H	07-02-19	1.992	1.999	4.133	120.0	11.56	22	0	10	75	55	86.51	90.62	40.58	0.40	NO
1_21_S2A	07-02-19	1.979	1.982	5.683	159.7	12.06	22	0	15	75	55	84.56	72.35	73.15	0.39	NO
1_21_S3G	07-05-19	2.003	2.003	5.532	154.0	11.27	24	0	10	72	52	65.28	65.64	43.00	0.38	NO
1_21_W4D	07-05-19	2.001	2.000	5.703	161.1	10.74	24	10	10	72	52	74.94	63.66	39.03	0.39	NO
1_22_N3G	07-05-19	1.982	1.977	4.588	140.7	11.01	24	0	15	75	52	100.79	102.13	44.87	0.43	NO
1_22_N4H	07-05-19	1.993	2.000	5.369	166.8	11.93	26	0	15	72	52	91.63	101.02	49.06	0.43	NO
1_23_N3C	07-06-19	1.984	1.972	5.145	161.0	11.32	28	0	10	75	52	111.81	131.10	57.98	0.44	NO

TABLE B.18: NAIL WITHDRAWAL DATA, SEASONED WOOD, CONTINUED

SAMPLE NUMBER	DATE	HEIGHT (in.)	WIDTH (in.)	LENGTH (in.)	WEIGHT (gm.)	M.C.% (%)	RINGS (/in.)	SAP WOO (%)	SUM WOO (%)	TEMP (F)	HUMIDI (%)	EXTRACTION FORCE AVG RAD (lbs.)	EXTRACTION FORCE AVG TAN (lbs.)	EXTRACTION FORCE AVG END (lbs.)	SPECIFIC GRAVITY	EXCL FLAG
1_23_N4D	07-07-19	1.991	1.999	5.707	185.7	10.99	42	0	10	75	52	137.98	142.62	74.14	0.45	NO
1_25_N4D	07-07-19	1.967	1.977	5.584	148.9	10.33	28	0	10	75	52	79.64	79.48	42.63	0.38	NO
1_25_S4D	07-05-19	2.006	2.007	5.265	143.8	10.32	34	0	10	72	52	74.01	94.78	40.24	0.38	NO
1_27_N4D	07-05-19	1.993	2.028	5.431	164.3	11.01	28	0	10	72	52	59.18	94.76	46.03	0.41	NO
1_28_N3A	07-05-19	2.001	2.002	5.449	164.2	11.32	26	0	10	72	52	62.93	80.11	43.19	0.41	NO
1_28_N4D	07-07-19	1.981	1.983	5.574	151.6	11.47	26	10	10	75	52	108.13	101.51	86.44	0.38	NO
1_29_E3C	07-02-19	2.004	2.008	4.229	126.7	11.27	30	10	10	75	55	70.48	87.35	51.73	0.41	NO
1_29_N2C	07-05-19	1.998	1.986	5.643	174.8	10.44	34	0	15	72	52	89.70	67.53	43.60	0.43	NO
1_4_N1D	07-07-19	1.992	1.981	5.363	149.4	11.17	28	0	10	75	52	109.93	124.66	62.34	0.39	NO
1_4_S1D	07-05-19	1.994	1.995	5.466	157.7	10.92	26	0	10	72	52	90.16	105.16	67.85	0.40	NO
1_4_W4D	07-05-19	1.971	1.983	5.681	150.4	11.41	26	35	15	72	52	78.51	83.58	45.94	0.37	NO
1_5_E3C	07-02-19	2.002	1.993	5.319	147.2	11.99	16	10	10	75	55	70.66	62.39	37.12	0.38	NO
1_5_E4H	07-02-19	1.844	1.846	5.422	128.3	12.01	18	15	15	75	55	65.54	61.89	44.15	0.38	NO
1_5_N1D	07-07-19	1.989	1.999	5.060	142.9	11.25	22	0	15	75	52	78.23	66.64	38.76	0.39	NO
1_5_N2C	07-02-19	2.011	1.991	5.986	169.0	11.77	20	0	15	75	55	59.98	71.32	49.24	0.39	NO
1_5_S2G	07-07-19	1.987	1.983	5.605	164.4	11.48	22	0	10	75	52	88.10	106.16	74.02	0.41	NO
1_5_W4J	07-05-19	1.981	1.977	3.947	107.2	11.09	22	0	10	72	52	78.47	69.45	37.75	0.38	NO
1_7_E3C	07-02-19	1.997	2.000	3.720	122.1	12.26	28	0	20	75	55	138.60	152.26	96.40	0.45	NO
1_7_W3C	07-05-19	1.989	1.993	5.668	180.7	11.99	32	0	15	72	52	99.49	92.92	62.64	0.44	NO

TABLE B.19: SPECIFIC GRAVITY AND SHRINKAGE IN VOLUME DATA, CONTINUED

SAMPLE NUMBER	DATE	SEASONING	HEIGHT (in.)	WIDTH (in.)	LENGTH (in.)	RINGS (/in.)	SAP WOO (%)	SUM WOO (%)	WEIGHT (gm.)	WAXED WEIGHT (gm.)	BOUYANT WEIGHT (gm.)	MOISTURE CONTENT (%)	VOLUME (cm.^3)	SPECIFIC GRAVITY	POUNDS PER CUB (pcf.)	VOLUMETRIC SHRINKAGE (%)
1_10_N1A	02-12-93	GREEN	5.712	1.988	1.987	38	0	20	204.1		162.2	34.10	366.30	0.416		
	09-08-93	AIRDRY	5.714	1.934	1.878				165.1		171.8	8.48	336.90	0.452		
	09-16-93	OVEN DRY	5.708	1.897	1.837				152.2	155.9	170.1	0.00	326.00	0.467	29.1	11.0
1_10_N4A	02-12-93	GREEN	5.864	1.987	1.992	24	50	10	231.2		144.2	60.97	375.36	0.383		
	09-08-93	AIRDRY	5.870	1.886	1.922				155.8		184.0	8.50	339.80	0.423		
	09-16-93	OVEN DRY	5.860	1.845	1.874				143.6	150.8	180.8	0.00	331.60	0.433	27.0	11.7
1_10_W4A	02-12-93	GREEN	5.792	2.007	2.020	22	30	15	226.1		154.9	58.33	381.00	0.375		
	09-08-93	AIRDRY	5.791	1.932	1.948				154.9		191.8	8.47	346.70	0.412		
	09-16-93	OVEN DRY	5.788	1.874	1.916				142.8	149.8	189.0	0.00	338.80	0.421	26.3	11.1
1_12_S4I	02-12-93	GREEN	4.631	2.014	2.014	20	0	15	157.6		147.7	35.05	305.30	0.382		
	09-08-93	AIRDRY	4.635	1.942	1.930				126.6		152.5	8.48	279.10	0.418		
	09-16-93	OVEN DRY	4.632	1.896	1.891				116.7	121.6	151.8	0.00	273.40	0.427	26.6	10.4
1_15_S1A	02-12-93	GREEN	5.320	2.017	2.019	20	0	10	177.3		173.9	37.66	351.20	0.367		
	09-08-93	AIRDRY	5.315	1.926	1.936				139.7		182.8	8.46	322.50	0.399		
	09-16-93	OVEN DRY	5.310	1.885	1.904				128.8	131.9	180.1	0.00	312.00	0.413	25.8	11.2
1_17_N3D	02-12-93	GREEN	6.180	2.015	2.006	16	0	15	224.1		183.6	33.63	407.70	0.411		
	09-08-93	AIRDRY	6.200	1.924	1.919				181.9		184.9	8.47	366.80	0.457		
	09-16-93	OVEN DRY	6.150	1.878	1.858				167.7	172.2	178.9	0.00	351.10	0.478	29.8	13.9
1_1_N2D	02-12-93	GREEN	5.743	2.003	2.015	28	5	10	205.5		171.5	47.52	377.00	0.369		
	09-08-93	AIRDRY	5.734	1.900	1.920				150.9		189.7	8.33	340.60	0.409		
	09-16-93	OVEN DRY	5.733	1.886	1.867				139.3	144.2	185.4	0.00	329.60	0.423	26.4	12.6
1_1_S4A	02-12-93	GREEN	5.926	2.011	2.022	16	5	7	185.6		204.7	38.40	390.30	0.344		
	09-08-93	AIRDRY	5.921	1.936	1.965				145.4		212.3	8.43	357.70	0.375		
	09-16-93	OVEN DRY	5.915	1.898	1.944				134.1	143.8	208.9	0.00	352.70	0.380	23.7	9.6
1_1_W3B	02-12-93	GREEN	5.899	2.018	2.007	18	0	25	203.1		184.4	30.36	387.50	0.402		
	09-08-93	AIRDRY	5.907	1.947	1.928				169.0		187.0	8.47	356.00	0.438		
	09-16-93	OVEN DRY	5.898	1.923	1.874				155.8	161.2	184.3	0.00	345.50	0.451	28.1	10.8

TABLE B.19: SPECIFIC GRAVITY AND SHRINKAGE IN VOLUME DATA, CONTINUED

SAMPLE NUMBER	DATE	SEASONING	HEIGHT (in.)	WIDTH (in.)	LENGTH (in.)	RINGS (/in.)	SAP WOO (%)	SUM WOO (%)	WEIGHT (gm.)	WAXED WEIGHT (gm.)	BOUYANT WEIGHT (gm.)	MOISTURE CONTENT (%)	VOLUME (cm.^3)	SPECIFIC GRAVITY	POUNDS PER CUB (pcf.)	VOLUMETRIC SHRINKAGE (%)
1_20_E4A1	02-12-93	GREEN	5.967	1.995	1.993	20	0	10	172.8		200.5	37.14	373.30	0.338		
	09-08-93	AIRDRY	5.967	1.946	1.882				136.7		204.3	8.49	341.00	0.370		
	09-16-93	OVEN DRY	5.906	1.936	1.837				126.0	139.7	195.1	0.00	334.80	0.376	23.5	10.3
1_20_E4A2	02-12-93	GREEN	5.911	1.997	2.009	20	0	7	172.3		185.6	34.29	357.90	0.358		
	09-08-93	AIRDRY	5.913	1.885	1.960				139.1		194.1	8.42	333.20	0.385		
	09-16-93	OVEN DRY	5.904	1.834	1.935				128.3	144.9	203.1	0.00	348.00	0.369	23.0	(2.8)
1_21_E4C	02-12-93	GREEN	5.841	2.010	2.006	24	75	10	248.6		134.1	90.64	382.70	0.341		
	09-08-93	AIRDRY	5.841	1.937	1.882				141.3		197.9	8.36	339.20	0.384		
	09-16-93	OVEN DRY	5.828	1.895	1.833				130.4	140.4	191.1	0.00	331.50	0.393	24.5	13.4
1_21_N1C	02-12-93	GREEN	5.513	2.040	2.000	20	0	10	174.0		185.4	35.73	359.40	0.357		
	09-08-93	AIRDRY	5.510	1.895	1.886				139.0		183.7	8.42	322.70	0.397		
	09-16-93	OVEN DRY	5.405	1.863	1.834				128.2	131.5	178.6	0.00	310.10	0.413	25.8	13.7
1_21_N4C	02-12-93	GREEN	6.035	2.002	2.005	26	30	10	252.1		140.8	82.95	392.90	0.351		
	09-08-93	AIRDRY	6.034	1.934	1.880				149.3		200.9	8.35	350.20	0.393		
	09-16-93	OVEN DRY	6.039	1.904	1.830				137.8	146.4	193.9	0.00	340.30	0.405	25.3	13.4
1_23_N3D	02-12-93	GREEN	5.785	2.009	2.014	32	0	10	207.4		174.6	38.27	382.00	0.393		
	09-08-93	AIRDRY	5.784	1.919	1.937				162.8		177.9	8.53	340.70	0.440		
	09-16-93	OVEN DRY	5.778	1.835	1.875				150.0	155.3	172.5	0.00	327.80	0.458	28.6	14.2
1_23_S3D	02-12-93	GREEN	5.816	2.018	2.006	38	10	10	227.1		156.6	49.51	383.70	0.396		
	09-08-93	AIRDRY	5.821	1.905	1.899				164.8		179.3	8.49	344.10	0.441		
	09-16-93	OVEN DRY	5.806	1.865	1.863				151.9	157.0	176.2	0.00	333.20	0.456	28.4	13.2
1_4_W3D	02-12-93	GREEN	5.477	2.046	2.046	24	15	10	222.0		151.4	62.88	373.40	0.365		
	09-08-93	AIRDRY	5.481	1.941	1.976				147.8		185.7	8.44	333.50	0.409		
	09-16-93	OVEN DRY	5.472	1.899	1.943				136.3	143.6	182.4	0.00	326.00	0.418	26.1	12.7
1_5_S1C	02-12-93	GREEN	5.922	2.011	2.013	22	0	15	179.1		211.1	32.67	390.20	0.346		
	09-08-93	AIRDRY	5.917	1.931	1.947				146.5		213.5	8.52	360.00	0.375		
	09-16-93	OVEN DRY	5.920	1.900	1.901				135.0	139.8	210.3	0.00	350.10	0.386	24.1	10.3

TABLE B.19: SPECIFIC GRAVITY AND SHRINKAGE IN VOLUME DATA, CONTINUED

SAMPLE NUMBER	DATE	SEASONING	HEIGHT (in.)	WIDTH (in.)	LENGTH (in.)	RINGS (/in.)	SAP WOO (%)	SUM WOO (%)	WEIGHT (gm.)	WAXED WEIGHT (gm.)	BOUYANT WEIGHT (gm.)	MOISTURE CONTENT (%)	VOLUME (cm.^3)	SPECIFIC GRAVITY	POUNDS PER CUB (pcf.)	VOLUMETRIC SHRINKAGE (%)
1_5_W3D	02-12-93	GREEN	5.942	2.000	2.007	28	25	10	209.1		177.3	57.45	386.40	0.344		
	09-08-93	AIRDRY	5.951	1.882	1.935				144.0		206.7	8.43	350.70	0.379		
	09-16-93	OVEN DRY	5.941	1.840	1.925				132.8	141.3	201.0	0.00	342.30	0.388	24.2	11.4
1_5_W3J	02-12-93	GREEN	4.829	2.012	2.010	16	0	10	148.9		169.1	33.90	318.00	0.350		
	09-08-93	AIRDRY	4.828	1.957	1.891				120.4		168.3	8.27	288.70	0.385		
	09-16-93	OVEN DRY	4.824	1.933	1.846				111.2	115.1	164.9	0.00	280.00	0.397	24.8	11.9

TABLE B.20: RADIAL AND TANGENTIAL SHRINKAGE DATA

SAMPLE NUMBER	DATE	SEASONING	TYPE	LOCATION	NOMINAL DIM. (IN.)	RINGS (/IN.)	SAP WOOD (%)	SUMMER WOOD (%)	WIDTH (IN.)	WEIGHT (GM.)	MOISTURE CONTENT (%)	SHRINKAGE (%)
10H	08-10-92	GREEN	RAD	PITH	1X1X4	20	0	15	3.8585	32.78	36.47	0.00
	08-13-92	AIR1							3.8180	30.01	24.94	1.05
	11-05-92	AIR2							3.6450	25.01	4.12	5.53
	11-24-92	OVEN							3.6195	24.02	0.00	6.19
19H	08-10-92	GREEN	RAD	PITH	1X1X4	28	0	15	4.0725	34.55	37.70	0.00
	08-13-92	AIR1							4.0360	31.14	24.11	0.90
	11-05-92	AIR2							3.8865	26.12	4.11	4.57
	11-24-92	OVEN							3.8640	25.09	0.00	5.12
1H	08-10-92	GREEN	RAD	PITH	1X1X4	20	0	10	4.1075	33.14	38.72	0.00
	08-13-92	AIR1							4.0395	28.81	20.59	1.66
	11-05-92	AIR2							3.9290	24.86	4.06	4.35
	11-24-92	OVEN							3.9070	23.89	0.00	4.88
20H	08-10-92	GREEN	RAD	PITH	1X1X4	22	0	15	4.1215	28.69	35.78	0.00
	08-13-92	AIR1							4.0715	25.91	22.62	1.21
	11-05-92	AIR2							3.9265	21.99	4.07	4.73
	11-24-92	OVEN							3.9005	21.13	0.00	5.36
21H	08-10-92	GREEN	RAD	PITH	1X1X4	22	0	20	3.9460	30.86	37.09	0.00
	08-13-92	AIR1							3.8865	26.52	17.81	1.51
	11-05-92	AIR2							3.7775	23.39	3.91	4.27
	11-24-92	OVEN							3.7440	22.51	0.00	5.12
27H	08-10-92	GREEN	RAD	PITH	1X1X4	24	0	10	4.0175	34.62	38.70	0.00
	08-13-92	AIR1							3.9655	30.26	21.23	1.29
	11-05-92	AIR2							3.8450	25.97	4.05	4.29
	11-24-92	OVEN							3.8285	24.96	0.00	4.70
28H	08-10-92	GREEN	RAD	PITH	1X1X4	25	0	15	4.0305	34.85	37.20	0.00
	08-13-92	AIR1							4.0020	31.46	23.86	0.71
	11-05-92	AIR2							3.8855	26.46	4.17	3.60
	11-24-92	OVEN							3.8555	25.40	0.00	4.34

TABLE B.20: RADIAL AND TANGENTIAL SHRINKAGE DATA, CONTINUED

SAMPLE NUMBER	DATE	SEASONING	TYPE	LOCATION	NOMINAL DIM. (IN.)	RINGS (/IN.)	SAP WOOD (%)	SUMMER WOOD (%)	WIDTH (IN.)	WEIGHT (GM.)	MOISTURE CONTENT (%)	SHRINKAGE (%)
2H	08-10-92	GREEN	RAD	PITH	1X1X4	40	0	15	3.6135	36.13	43.72	0.00
	08-13-92	AIR1							3.5765	31.12	23.79	1.02
	11-05-92	AIR2							3.4530	26.14	3.98	4.44
	11-24-92	OVEN							3.4310	25.14	0.00	5.05
10NS	08-10-92	GREEN	RAD	SAP	1X1X3	28	50	20	2.5405	25.44	80.43	0.00
	08-13-92	AIR1							2.5180	20.64	46.38	0.89
	11-05-92	AIR2							2.4420	17.78	26.10	3.88
	11-24-92	OVEN							2.4275	14.10	0.00	4.45
10SS	08-10-92	GREEN	RAD	SAP	1X1X3	26	50	15	2.8095	29.75	56.99	0.00
	08-13-92	AIR1							2.7915		-100.00	0.64
	11-05-92	AIR2							2.6905	19.61	3.48	4.24
	11-24-92	OVEN							2.6775	18.95	0.00	4.70
19NS	08-10-92	GREEN	RAD	SAP	1X1X3	20	40	10	3.0930	35.00	93.80	0.00
	08-13-92	AIR1							3.0850	28.02	55.15	0.26
	11-05-92	AIR2							2.9690	18.79	4.04	4.01
	11-24-92	OVEN							2.9510	18.06	0.00	4.59
19SS	08-10-92	GREEN	RAD	SAP	1X1X3	18	50	10	2.7760	28.16	69.23	0.00
	08-13-92	AIR1							2.7600	20.89	25.54	0.58
	11-05-92	AIR2							2.6635	17.23	3.55	4.05
	11-24-92	OVEN							2.6540	16.64	0.00	4.39
1NS	08-10-92	GREEN	RAD	SAP	1X1X4	22	30	15	3.6650	35.23	59.05	0.00
	08-13-92	AIR1							3.6185	26.58	20.00	1.27
	11-05-92	AIR2							3.5240	23.01	3.88	3.85
	11-24-92	OVEN							3.5075	22.15	0.00	4.30
1SS	08-10-92	GREEN	RAD	SAP	1X1X4	22	30	10	3.9615	40.42	63.18	0.00
	08-13-92	AIR1							3.9410	34.05	37.46	0.52
	11-05-92	AIR2							3.7970	25.77	4.04	4.15
	11-24-92	OVEN							3.7720	24.77	0.00	4.78

TABLE B.20: RADIAL AND TANGENTIAL SHRINKAGE DATA, CONTINUED

SAMPLE NUMBER	DATE	SEASONING	TYPE	LOCATION	NOMINAL DIM. (IN.)	RINGS (/IN.)	SAP WOOD (%)	SUMMER WOOD (%)	WIDTH (IN.)	WEIGHT (GM.)	MOISTURE CONTENT (%)	SHRINKAGE (%)
20SS	08-10-92	GREEN	RAD	SAP	1X1X3	18	20	20	3.3520	26.61	35.83	0.00
	08-13-92	AIR1							3.3465	25.50	30.17	0.16
	11-05-92	AIR2							3.2565	20.47	4.49	2.85
	11-24-92	OVEN							3.2390	19.59	0.00	3.37
21NS	08-10-92	GREEN	RAD	SAP	1X1X4	26	20	15	3.4375	30.58	58.86	0.00
	08-13-92	AIR1							3.4385	27.68	43.79	-0.03
	11-05-92	AIR2							3.2815	20.03	4.05	4.54
	11-24-92	OVEN							3.2620	19.25	0.00	5.11
27NS	08-10-92	GREEN	RAD	SAP	1X1X3	30	70	15	2.5665	22.03	37.00	0.00
	08-13-92	AIR1							2.5625	20.37	26.68	0.16
	11-05-92	AIR2							2.4475	16.72	3.98	4.64
	11-24-92	OVEN							2.4295	16.08	0.00	5.34
27SS	08-10-92	GREEN	RAD	SAP	1X1X3	30	70	10	2.5160	26.24	65.24	0.00
	08-13-92	AIR1							2.5000	20.67	30.16	0.64
	11-05-92	AIR2							2.4180	16.48	3.78	3.90
	11-24-92	OVEN							2.4030	15.88	0.00	4.49
28NS	08-10-92	GREEN	RAD	SAP	1X1X3	30	50	15	2.6270	25.51	63.00	0.00
	08-13-92	AIR1							2.6125	20.22	29.20	0.55
	11-05-92	AIR2							2.5305	16.27	3.96	3.67
	11-24-92	OVEN							2.5160	15.65	0.00	4.23
28SS	08-10-92	GREEN	RAD	SAP	1X1X3	32	50	15	2.2675	23.14	72.69	0.00
	08-13-92	AIR1							2.2625	18.18	35.67	0.22
	11-05-92	AIR2							2.1955	13.93	3.96	3.18
	11-24-92	OVEN							2.1840	13.40	0.00	3.68
2NS	08-10-92	GREEN	RAD	SAP	1X1X3	24	50	15	2.7765	31.93	88.27	0.00
	08-13-92	AIR1							2.7720	26.48	56.13	0.16
	11-05-92	AIR2							2.6730	17.53	3.36	3.73
	11-24-92	OVEN							2.6665	16.96	0.00	3.96

TABLE B.20: RADIAL AND TANGENTIAL SHRINKAGE DATA, CONTINUED

SAMPLE NUMBER	DATE	SEASONING	TYPE	LOCATION	NOMINAL DIM. (IN.)	RINGS (/IN.)	SAP WOOD (%)	SUMMER WOOD (%)	WIDTH (IN.)	WEIGHT (GM.)	MOISTURE CONTENT (%)	SHRINKAGE (%)
2SS	08-10-92	GREEN	RAD	SAP	1X1X3	32	70	15	2.1745	22.57	77.30	0.00
	08-13-92	AIR1							2.1650	17.38	36.53	0.44
	11-05-92	AIR2							2.0880	13.22	3.85	3.98
	11-24-92	OVEN							2.0750	12.73	0.00	4.58
10EH	08-10-92	GREEN	TAN	PITH	1X1X4	20	0	30	4.0245	35.66	16.31	0.00
	08-13-92	AIR1							3.9815	37.50	22.31	1.07
	11-05-92	AIR2							3.8330	31.96	4.24	4.76
	11-24-92	OVEN							3.8025	30.66	0.00	5.52
10WH	08-10-92	GREEN	TAN	PITH	1X1X4	20	0	15	4.0530	35.32	35.48	0.00
	08-13-92	AIR1							4.0040	32.45	24.47	1.21
	11-05-92	AIR2							3.8010	27.07	3.84	6.22
	11-24-92	OVEN							3.7685	26.07	0.00	7.02
19EH	08-10-92	GREEN	TAN	PITH	1X1X4	28	0	15	4.1340	34.21	40.03	0.00
	08-13-92	AIR1							4.0605	29.68	21.49	1.78
	11-05-92	AIR2							3.8615	25.35	3.77	6.59
	11-24-92	OVEN							3.8225	24.43	0.00	7.54
19WH	08-10-92	GREEN	TAN	PITH	1X1X4	24	0	10	4.1120	34.24	44.23	0.00
	08-13-92	AIR1							4.1020	31.22	31.51	0.24
	11-05-92	AIR2							3.8180	24.63	3.75	7.15
	11-24-92	OVEN							3.7820	23.74	0.00	8.03
1EH	08-10-92	GREEN	TAN	PITH	1X1X4	26	0	15	4.0855	33.36	35.17	0.00
	08-13-92	AIR1							3.9960	29.58	19.85	2.19
	11-05-92	AIR2							3.8150	25.68	4.05	6.62
	11-24-92	OVEN							3.7675	24.68	0.00	7.78
1WH	08-10-92	GREEN	TAN	PITH	1X1X4	28	0	10	4.0970	34.49	34.62	0.00
	08-13-92	AIR1							4.0135	30.92	20.69	2.04
	11-05-92	AIR2							3.8095	26.63	3.94	7.02
	11-24-92	OVEN							3.7715	25.62	0.00	7.94

TABLE B.20: RADIAL AND TANGENTIAL SHRINKAGE DATA, CONTINUED

SAMPLE NUMBER	DATE	SEASONING	TYPE	LOCATION	NOMINAL DIM. (IN.)	RINGS (/IN.)	SAP WOOD (%)	SUMMER WOOD (%)	WIDTH (IN.)	WEIGHT (GM.)	MOISTURE CONTENT (%)	SHRINKAGE (%)
20EH	08-10-92	GREEN	TAN	PITH	1X1X4	26	0	15	3.9695	27.29	36.65	0.00
	08-13-92	AIR1							3.9150	25.05	25.44	1.37
	11-05-92	AIR2							3.7115	20.79	4.11	6.50
	11-24-92	OVEN							3.6690	19.97	0.00	7.57
20WH	08-10-92	GREEN	TAN	PITH	1X1X4	24	0	20	3.9875	30.69	33.90	0.00
	08-13-92	AIR1							3.9640	29.25	27.62	0.59
	11-05-92	AIR2							3.7575	23.86	4.10	5.77
	11-24-92	OVEN							3.7350	22.92	0.00	6.33
21EH	08-10-92	GREEN	TAN	PITH	1X1X4	28	0	10	4.0450	32.70	38.09	0.00
	08-13-92	AIR1							3.9570	28.81	21.66	2.18
	11-05-92	AIR2							3.7460	24.63	4.01	7.39
	11-24-92	OVEN							3.7115	23.68	0.00	8.24
21WH	08-10-92	GREEN	TAN	PITH	1X1X4	26	0	15	4.0920	32.51	34.56	0.00
	08-13-92	AIR1							3.9920	28.58	18.29	2.44
	11-05-92	AIR2							3.8135	25.11	3.93	6.81
	11-24-92	OVEN							3.7835	24.16	0.00	7.54
27EH	08-10-92	GREEN	TAN	PITH	1X1X4	26	0	15	3.9850	33.57	35.42	0.00
	08-13-92	AIR1							3.9020	30.01	21.06	2.08
	11-05-92	AIR2							3.7345	25.74	3.83	6.29
	11-24-92	OVEN							3.6920	24.79	0.00	7.35
27WH	08-10-92	GREEN	TAN	PITH	1X1X4	26	0	15	4.0630	34.80	36.79	0.00
	08-13-92	AIR1							4.0430	32.68	28.46	0.49
	11-05-92	AIR2							3.7885	26.47	4.05	6.76
	11-24-92	OVEN							3.7655	25.44	0.00	7.32
28EH	08-10-92	GREEN	TAN	PITH	1X1X4	28	0	20	4.0945	33.12	32.59	0.00
	08-13-92	AIR1							4.0605	31.50	26.10	0.83
	11-05-92	AIR2							3.8500	25.96	3.92	5.97
	11-24-92	OVEN							3.8205	24.98	0.00	6.69

TABLE B.20: RADIAL AND TANGENTIAL SHRINKAGE DATA, CONTINUED

SAMPLE NUMBER	DATE	SEASONING	TYPE	LOCATION	NOMINAL DIM. (IN.)	RINGS (/IN.)	SAP WOOD (%)	SUMMER WOOD (%)	WIDTH (IN.)	WEIGHT (GM.)	MOISTURE CONTENT (%)	SHRINKAGE (%)
28WH	08-10-92	GREEN	TAN	PITH	1X1X4	26	0	20	4.0365	32.03	33.13	0.00
	08-13-92	AIR1							3.9600	29.00	20.53	1.90
	11-05-92	AIR2							3.7975	25.02	3.99	5.92
	11-24-92	OVEN							3.7615	24.06	0.00	6.81
2EH	08-10-92	GREEN	TAN	PITH	1X1X4	32	0	15	4.0215	34.07	41.31	0.00
	08-13-92	AIR1							3.9690	30.07	24.72	1.31
	11-05-92	AIR2							3.7445	25.18	4.44	6.89
	11-24-92	OVEN							3.7065	24.11	0.00	7.83
2WH	08-10-92	GREEN	TAN	PITH	1X1X4	36	0	15	4.0285	40.50	55.11	0.00
	08-13-92	AIR1							3.9905	32.79	25.58	0.94
	11-05-92	AIR2							3.7820	27.19	4.14	6.12
	11-24-92	OVEN							3.7485	26.11	0.00	6.95
10ES	08-10-92	GREEN	TAN	SAP	1X1X4	20	60	20	4.0595	53.01	72.33	0.00
	08-13-92	AIR1							4.0260	39.58	28.67	0.83
	11-05-92	AIR2							3.7960	32.08	4.29	6.49
	11-24-92	OVEN							3.7610	30.76	0.00	7.35
10WS	08-10-92	GREEN	TAN	SAP	1X1X4	26	60	15	4.0040	44.40	73.71	0.00
	08-13-92	AIR1							3.9630	34.07	33.29	1.02
	11-05-92	AIR2							3.7145	26.58	3.99	7.23
	11-24-92	OVEN							3.6775	25.56	0.00	8.15
19ES	08-10-92	GREEN	TAN	SAP	1X1X4	16	100	15	4.0985	49.42	105.40	0.00
	08-13-92	AIR1							4.1010	45.23	87.99	-0.06
	11-05-92	AIR2							3.8195	25.06	4.16	6.81
	11-24-92	OVEN							3.7815	24.06	0.00	7.73
19WS	08-10-92	GREEN	TAN	SAP	1X1X4	16	100	15	4.1135	59.70	144.57	0.00
	08-13-92	AIR1							4.1140	42.26	73.13	-0.01
	11-05-92	AIR2							3.8110	25.42	4.14	7.35
	11-24-92	OVEN							3.7735	24.41	0.00	8.27

TABLE B.20: RADIAL AND TANGENTIAL SHRINKAGE DATA, CONTINUED

SAMPLE NUMBER	DATE	SEASONING	TYPE	LOCATION	NOMINAL DIM. (IN.)	RINGS (/IN.)	SAP WOOD (%)	SUMMER WOOD (%)	WIDTH (IN.)	WEIGHT (GM.)	MOISTURE CONTENT (%)	SHRINKAGE (%)
1ES	08-10-92	GREEN	TAN	SAP	1X1X4	18	90	15	4.0665	53.91	128.63	0.00
	08-13-92	AIR1							4.0580	35.82	51.91	0.21
	11-05-92	AIR2							3.7780	24.49	3.86	7.09
	11-24-92	OVEN							3.7295	23.58	0.00	8.29
1WS	08-10-92	GREEN	TAN	SAP	1X1X4	20	100	10	4.0325	55.25	132.63	0.00
	08-13-92	AIR1							4.0205	33.23	39.92	0.30
	11-05-92	AIR2							3.7440	24.74	4.17	7.15
	11-24-92	OVEN							3.7075	23.75	0.00	8.06
20ES	08-10-92	GREEN	TAN	SAP	1X1X4	18	60	15	4.0980	34.65	43.00	0.00
	08-13-92	AIR1							4.0860	31.86	31.49	0.29
	11-05-92	AIR2							3.7840	25.25	4.21	7.66
	11-24-92	OVEN							3.7515	24.23	0.00	8.46
20WS	08-10-92	GREEN	TAN	SAP	1X1X4	16	60	20	4.0175	36.91	42.79	0.00
	08-13-92	AIR1							4.0010	33.00	27.66	0.41
	11-05-92	AIR2							3.7305	26.92	4.14	7.14
	11-24-92	OVEN							3.6985	25.85	0.00	7.94
21ES	08-10-92	GREEN	TAN	SAP	1X1X4	22	80	15	3.5525	33.48	61.74	0.00
	08-13-92	AIR1							3.5265	27.00	30.43	0.73
	11-05-92	AIR2							3.4060	21.54	4.06	4.12
	11-24-92	OVEN							3.3850	20.70	0.00	4.71
21WS	08-10-92	GREEN	TAN	SAP	1X1X4	30	90	15	4.0265	39.48	69.51	0.00
	08-13-92	AIR1							4.0270	35.26	51.40	-0.01
	11-05-92	AIR2							3.7015	24.21	3.95	8.07
	11-24-92	OVEN							3.6595	23.29	0.00	9.11
27ES	08-10-92	GREEN	TAN	SAP	1X1X4	30	90	15	4.0300	39.86	56.68	0.00
	08-13-92	AIR1							3.9965	32.79	28.89	0.83
	11-05-92	AIR2							3.7630	26.49	4.13	6.63
	11-24-92	OVEN							3.7360	25.44	0.00	7.30

TABLE B.20: RADIAL AND TANGENTIAL SHRINKAGE DATA, CONTINUED

SAMPLE NUMBER	DATE	SEASONING	TYPE	LOCATION	NOMINAL DIM. (IN.)	RINGS (/IN.)	SAP WOOD (%)	SUMMER WOOD (%)	WIDTH (IN.)	WEIGHT (GM.)	MOISTURE CONTENT (%)	SHRINKAGE (%)
27WS	08-10-92	GREEN	TAN	SAP	1X1X4	26	90	15	4.0400	39.17	59.81	0.00
	08-13-92	AIR1							4.0345	35.05	43.00	0.14
	11-05-92	AIR2							3.7780	25.52	4.12	6.49
	11-24-92	OVEN							3.7405	24.51	0.00	7.41
28ES	08-10-92	GREEN	TAN	SAP	1X1X4	30	80	15	4.1045	48.33	99.79	0.00
	08-13-92	AIR1							4.0980	34.95	44.48	0.16
	11-05-92	AIR2							3.8375	25.13	3.89	6.51
	11-24-92	OVEN							3.7990	24.19	0.00	7.44
28WS	08-10-92	GREEN	TAN	SAP	1X1X4	30	70	15	4.0245	49.23	110.03	0.00
	08-13-92	AIR1							4.0050	31.52	34.47	0.48
	11-05-92	AIR2							3.7750	24.39	4.05	6.20
	11-24-92	OVEN							3.7390	23.44	0.00	7.09
2ES	08-10-92	GREEN	TAN	SAP	1X1X4	20	80	15	4.0875	64.20	148.93	0.00
	08-13-92	AIR1							4.0825	47.62	84.65	0.12
	11-05-92	AIR2							3.8430	26.86	4.15	5.98
	11-24-92	OVEN							3.8190	25.79	0.00	6.57
2WS	08-10-92	GREEN	TAN	SAP	1X1X4	26	70	15	4.0250	60.13	154.46	0.00
	08-13-92	AIR1							4.0175	48.27	104.27	0.19
	11-05-92	AIR2							3.7335	24.60	4.10	7.24
	11-24-92	OVEN							3.6895	23.63	0.00	8.34

APPENDIX C: HISTOGRAMS AND PROBABILITY DENSITY DISTRIBUTIONS

The figures contained in this appendix show the histograms and probability density functions fitted to the test data collected throughout the course of this study. These graphs serve to provide a visual indication of the variability present within a data set. The graphs also serve to demonstrate the relative ability of each of the probability density functions to represent the data set.

The graphs were used to aid in the selection of mechanical properties values to be used in creating the allowable design values for Alaskan White Spruce, as discussed in Sections 5.5 and Appendix E. As such, the graphs supplement the χ^2 test for selection of mechanical properties values.

The three probability distributions shown in the graphs are the normal, the log normal, and the Weibull distributions. These three distributions are discussed in Section 5.3. The histogram is created using methodologies discussed in Section 5.2.

A graph is given for each mechanical property studied during this project. Where appropriate, graphs are given for the two standardized moisture content levels: green wood with M.C. > 27% and seasoned wood, with M.C. = 12%. Table C.1 may be used to identify the particular figure that is associated with a given property.

TABLE C.1: INDEX TO HISTOGRAM FIGURES

TEST TYPE	STRENGTH		MODULUS OF ELASTICITY		MISCELLANEOUS	
	GREEN	MC=12%	GREEN	MC=12%	GREEN	MC=12%
BENDING	C.1	C.2	C.3	C.4		
PARALLEL COMPRESSION	C.5	C.6	C.7	C.8		
PERPEND. COMPRESSION						
AT P.L.	C.9	C.10	C.13	C.14		
AT .04"	C.11	C.12				
PARALLEL TENSION		C.15		C.16		
SHEAR STRENGTH	C.17	C.18				
PERPEND. TENSION	C.19	C.20				
CLEAVAGE	C.21	C.22				
HARDNESS						
RAD AND TAN					C.23	C.24
END					C.25	C.26
NAIL WITHDRAWAL						
RAD AND TAN					C.27	C.28
END					C.29	C.30
SHRINKAGE						
VOLUMMETRIC					C.31	
RADIAL					C.32	
TANGENTIAL					C.33	
SPECIFIC GRAVITY					C.34	C.35

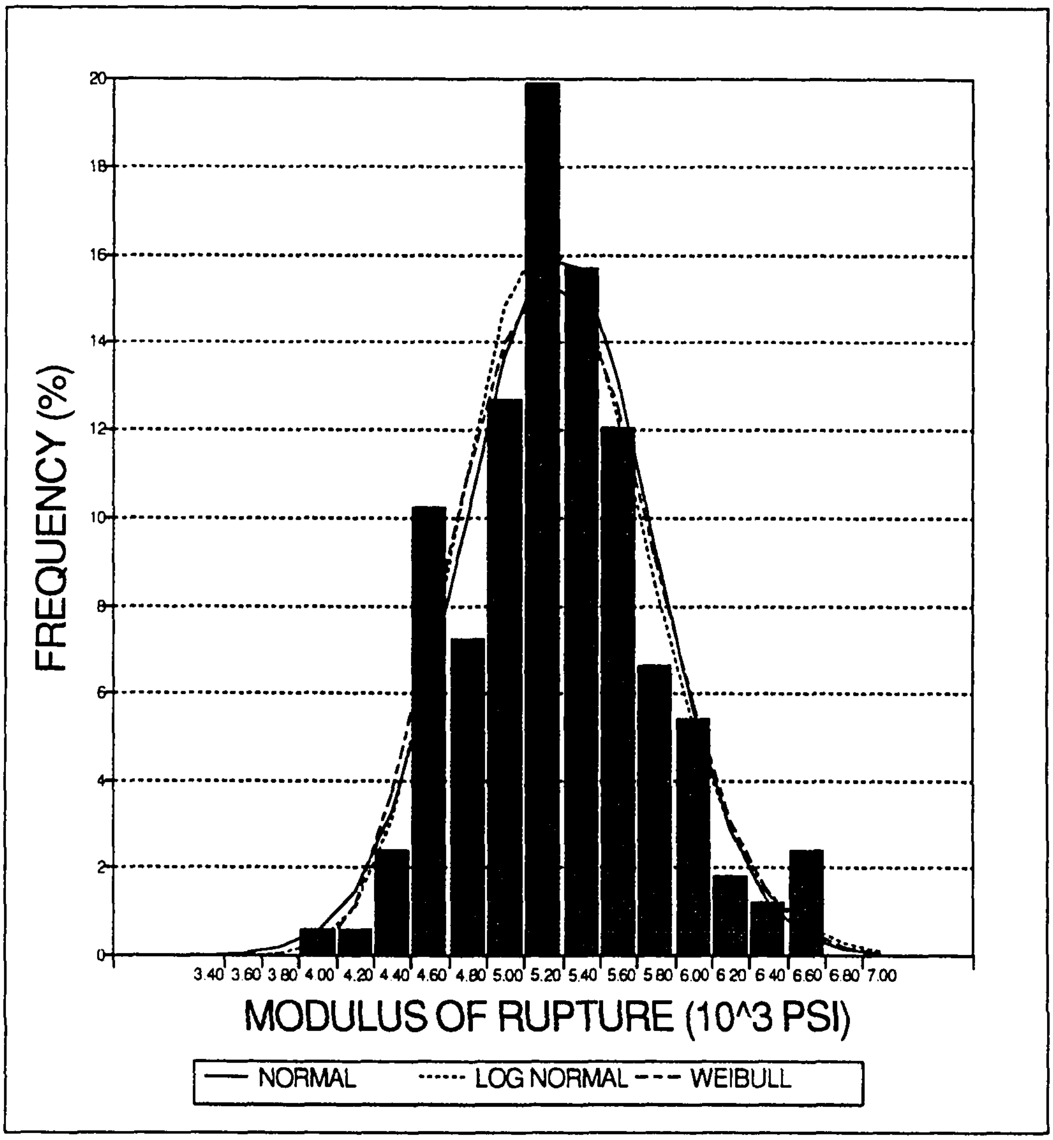


FIGURE C.1: FLEXURAL MODULUS OF RUPTURE, GREEN WOOD

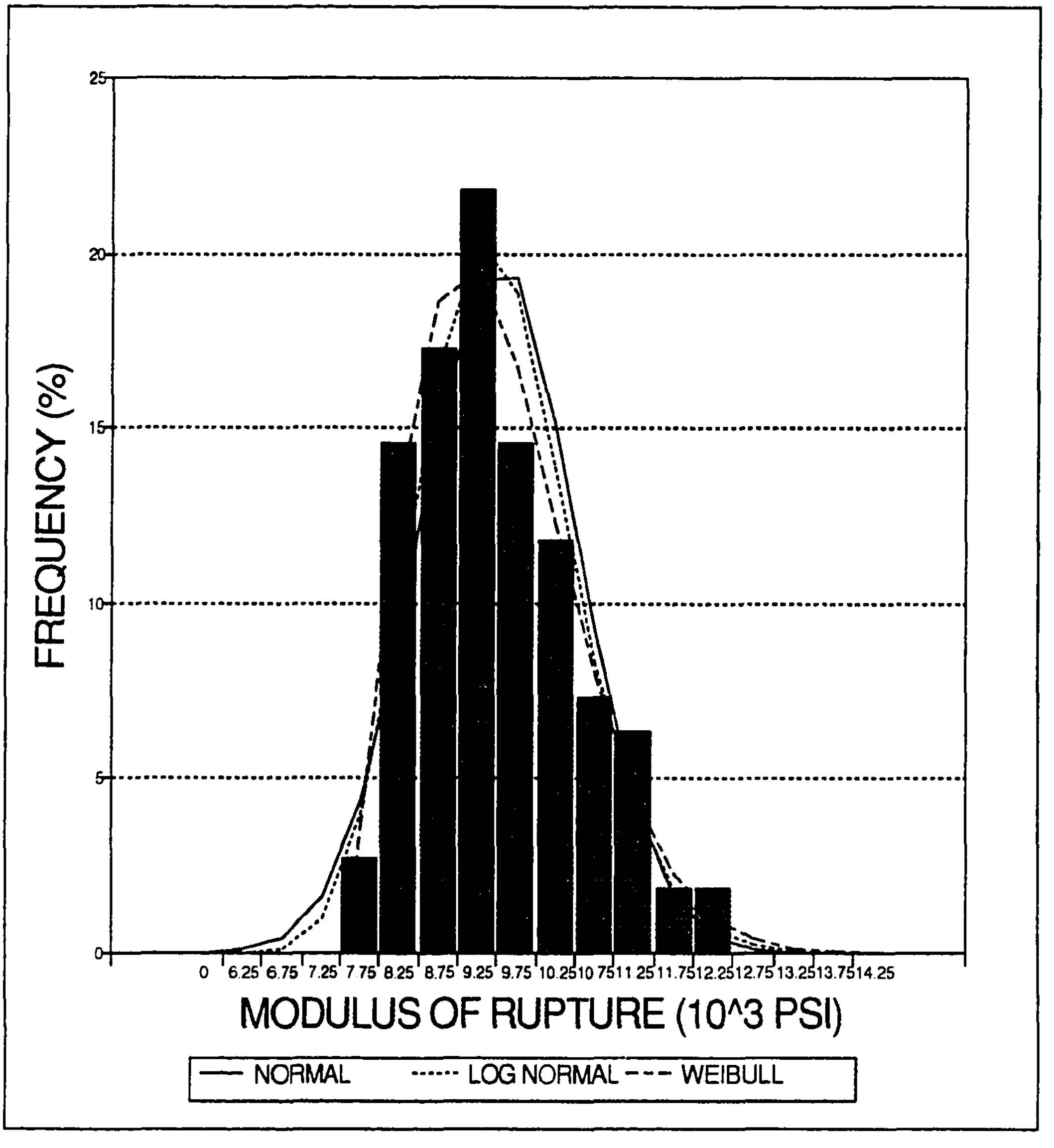


FIGURE C.2: FLEXURAL MODULUS OF RUPTURE, M.C. = 12%

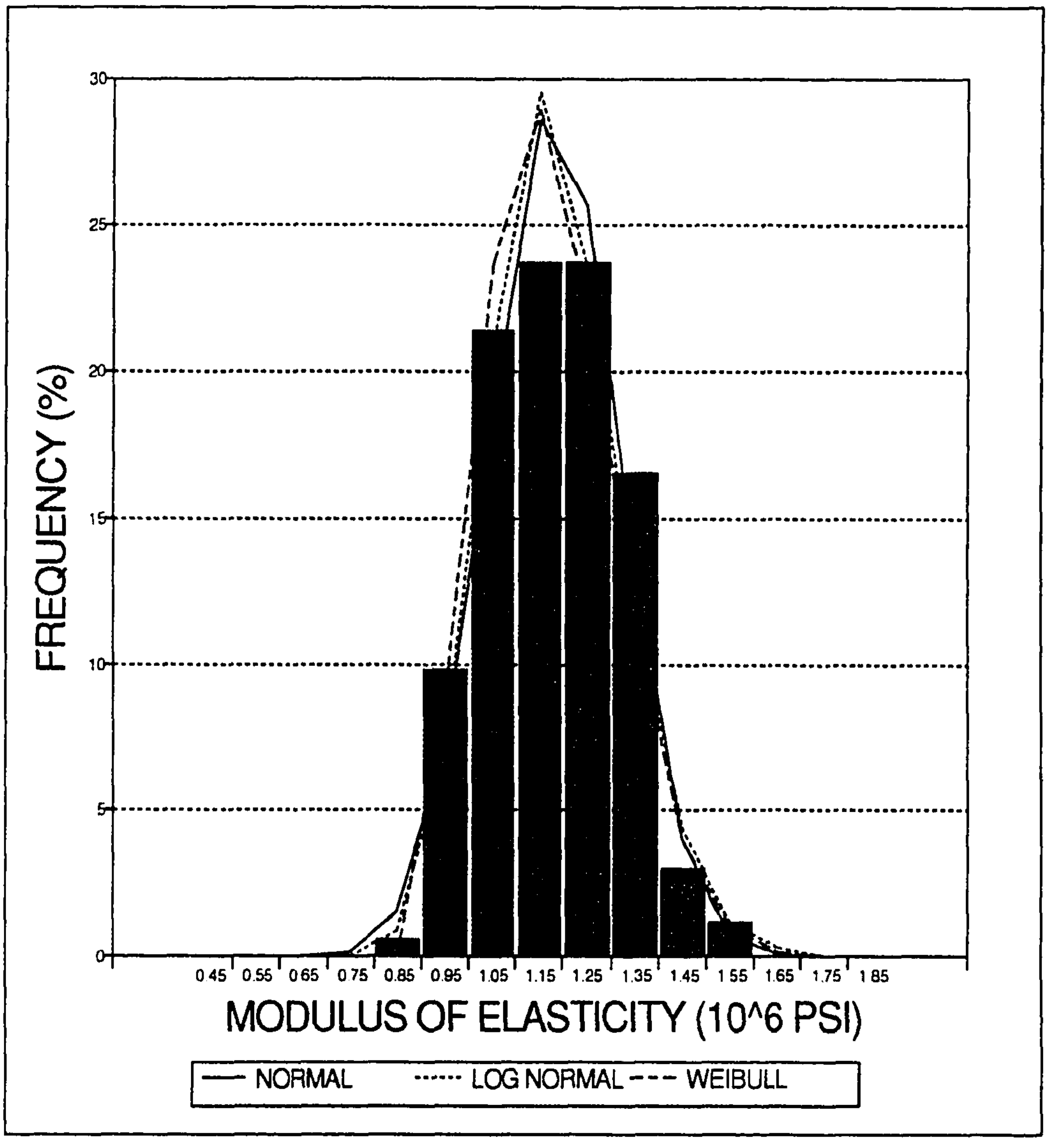


FIGURE C.3: FLEXURAL MODULUS OF ELASTICITY, GREEN WOOD

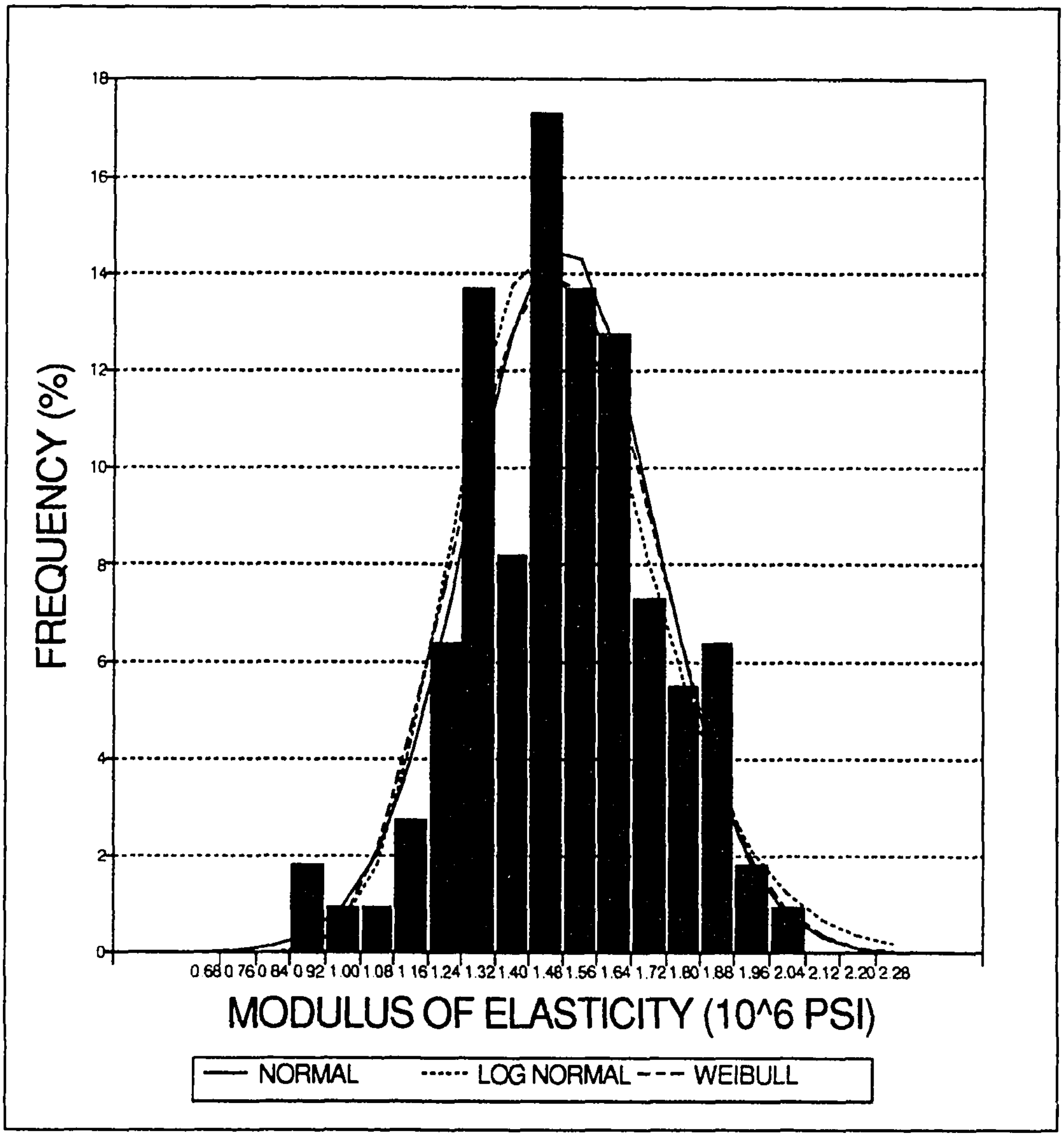


FIGURE C.4: FLEXURAL MODULUS OF ELASTICITY, M.C. = 12%

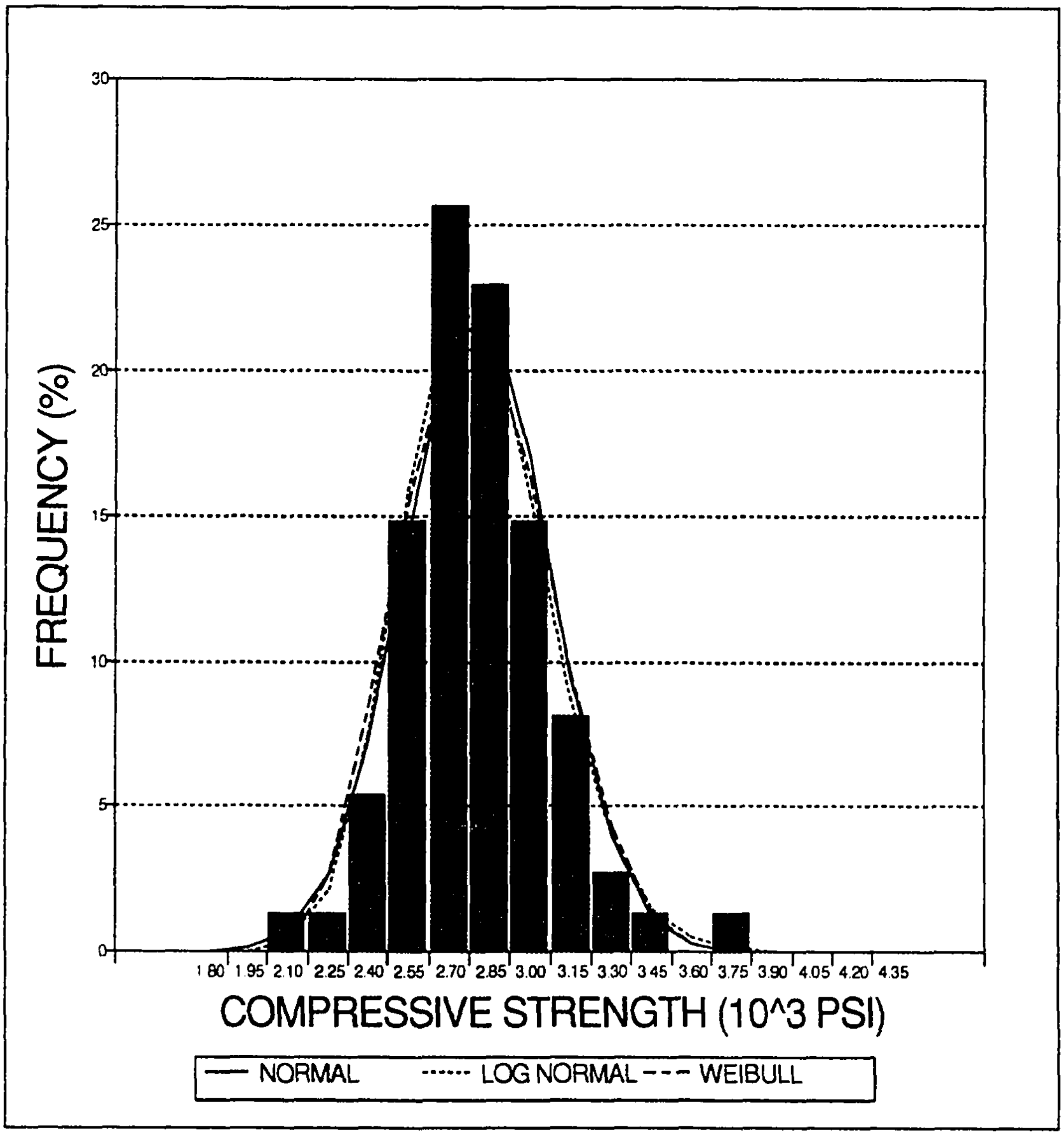


FIGURE C.5: PARALLEL TO GRAIN COMPRESSIVE STRENGTH, GREEN WOOD

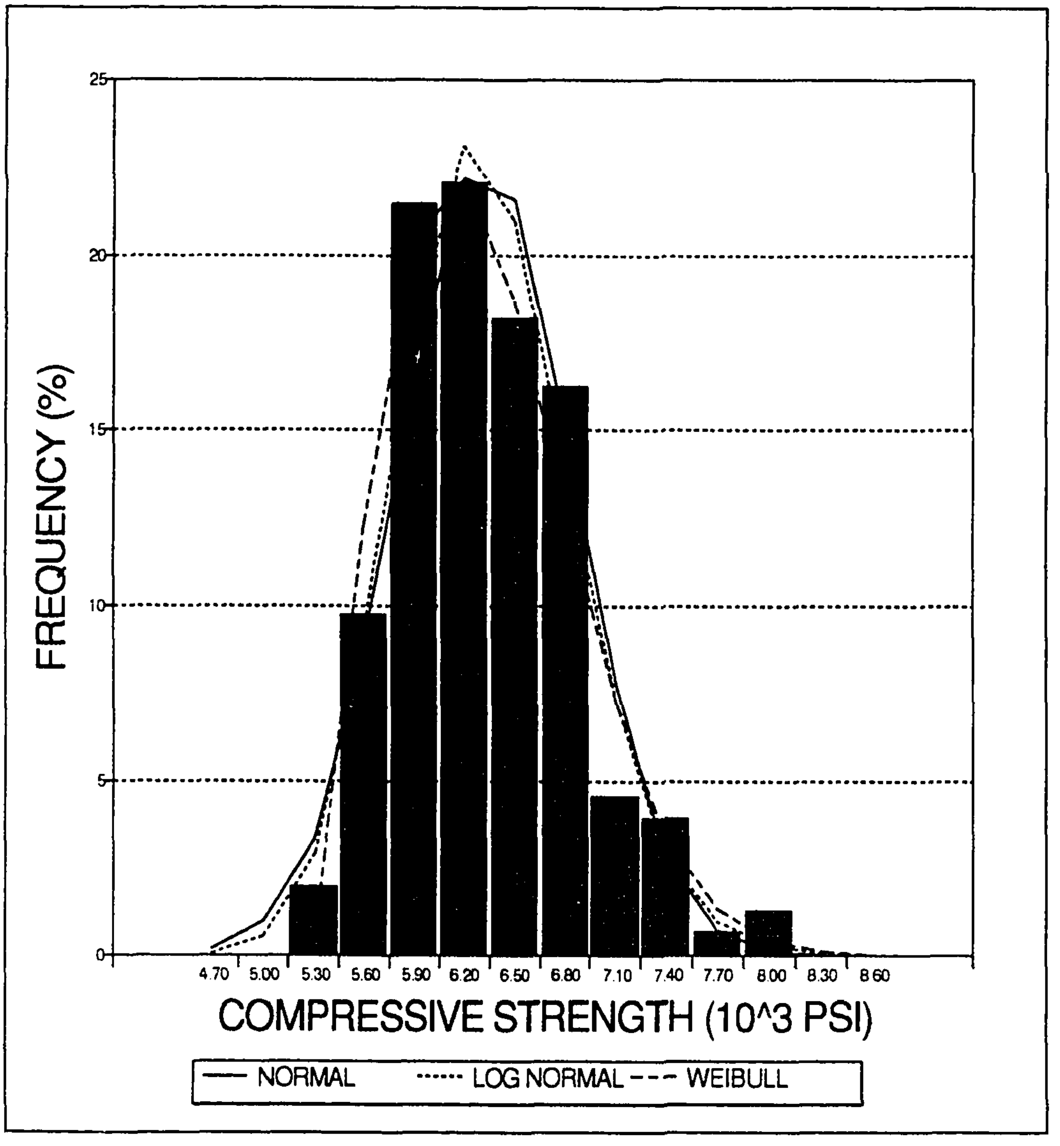


FIGURE C.6: PARALLEL TO GRAIN COMPRESSIVE STRENGTH, M.C. = 12%

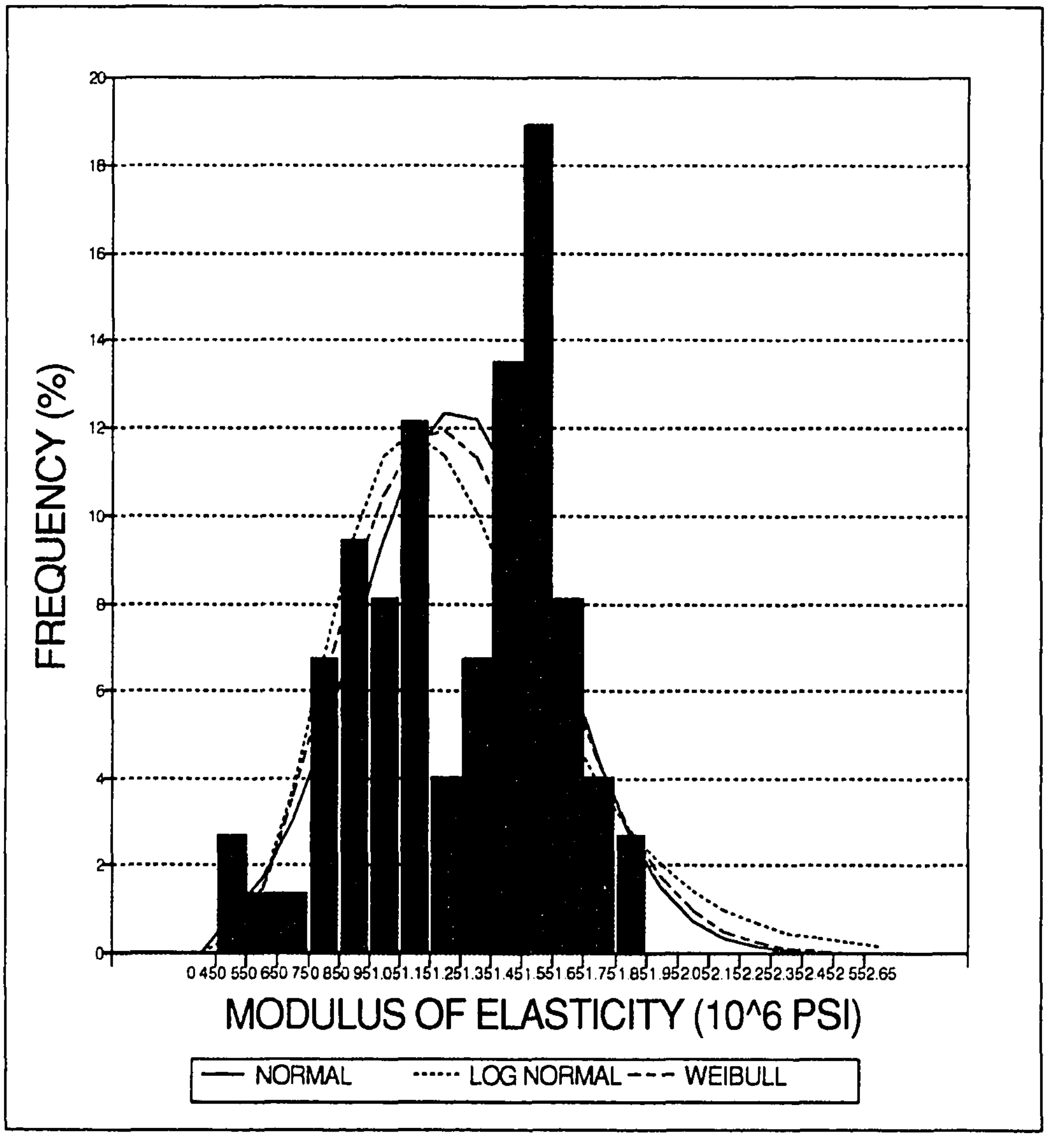


FIGURE C.7: PARALLEL TO GRAIN
COMPRESSIVE MODULUS OF ELASTICITY, GREEN WOOD

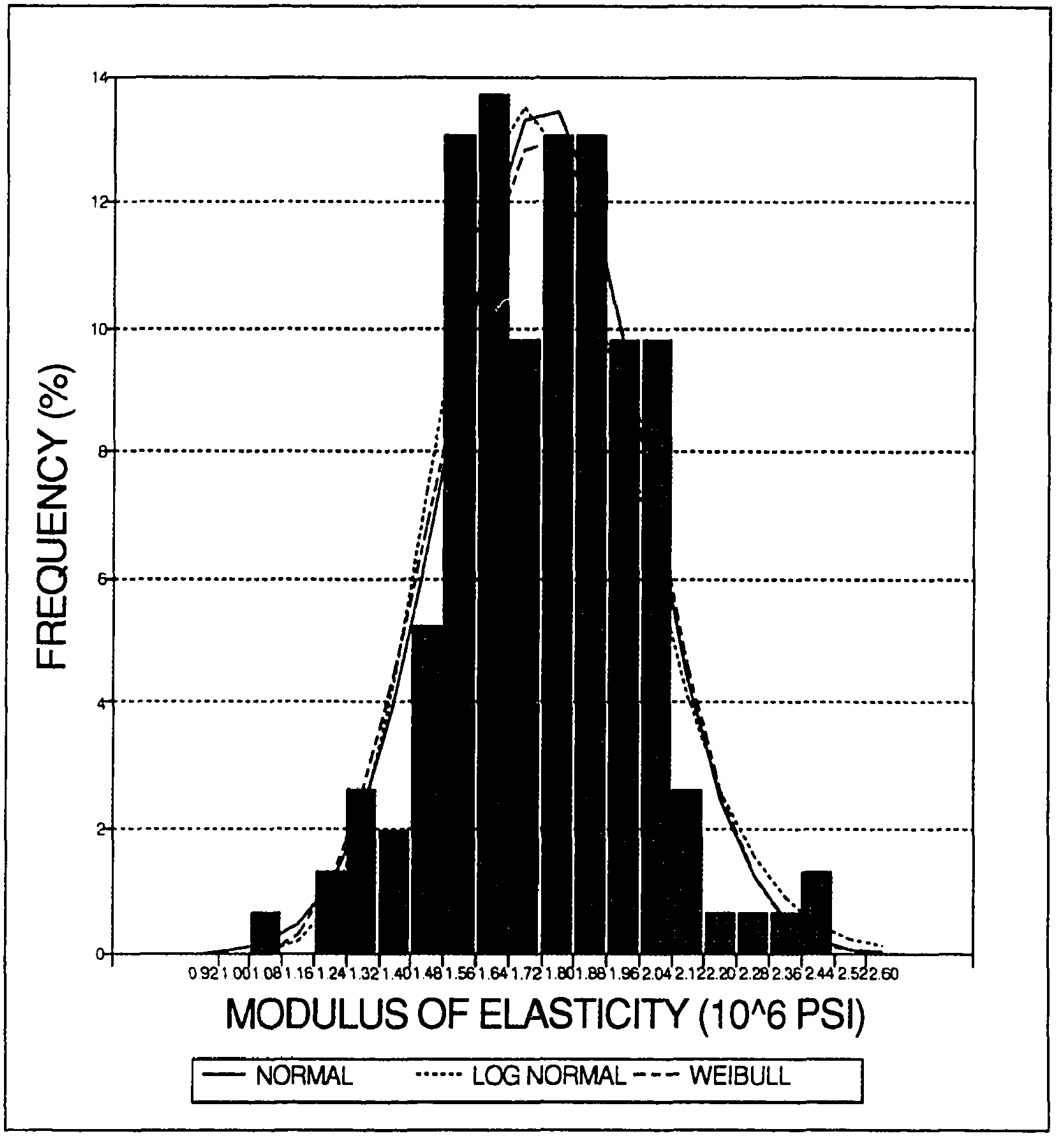


FIGURE C.8: PARALLEL TO GRAIN
COMPRESSIVE MODULUS OF ELASTICITY, M.C. = 12%

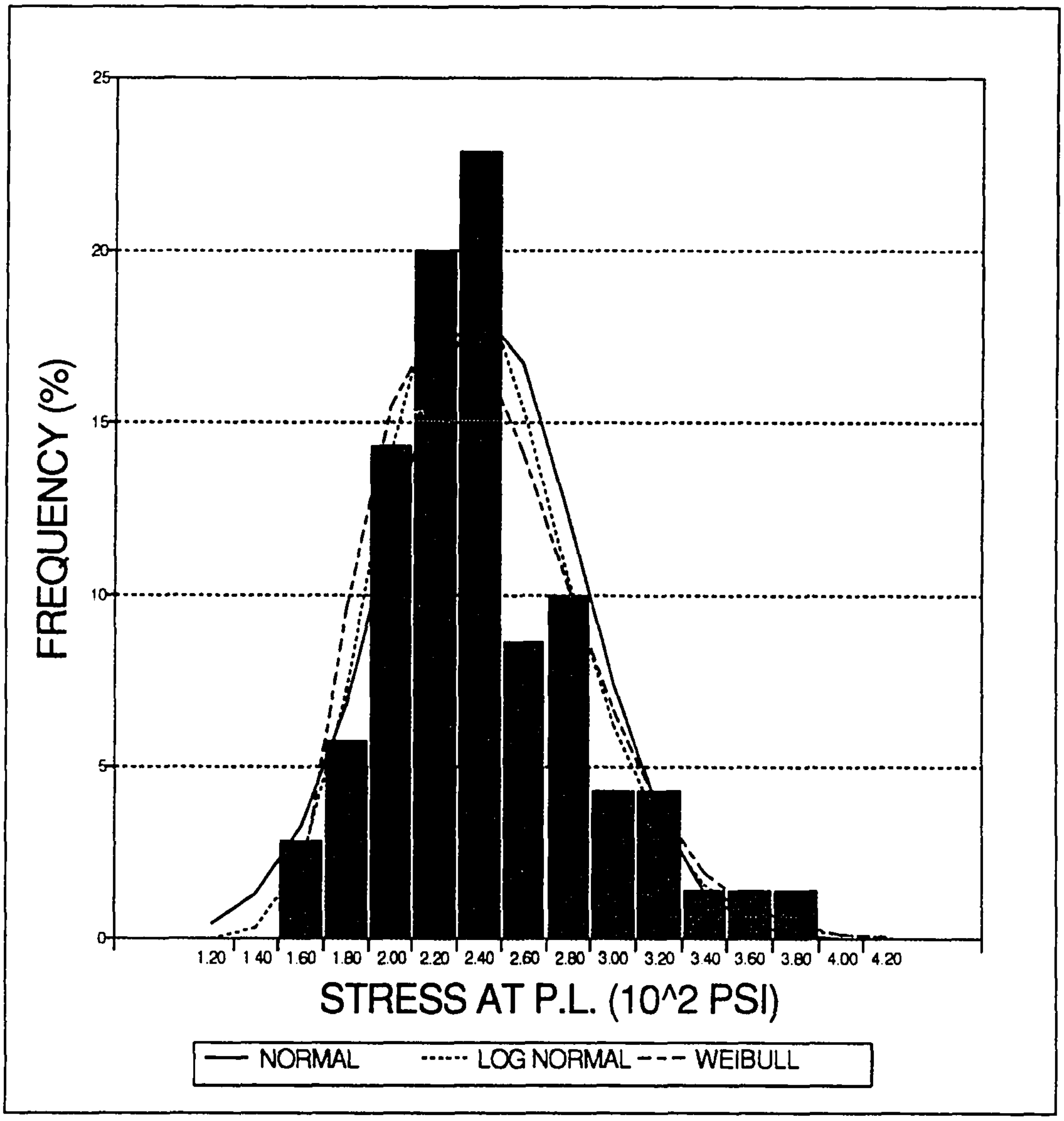


FIGURE C.9: PERPENDICULAR COMPRESSION
STRESS AT P.L. GREEN WOOD

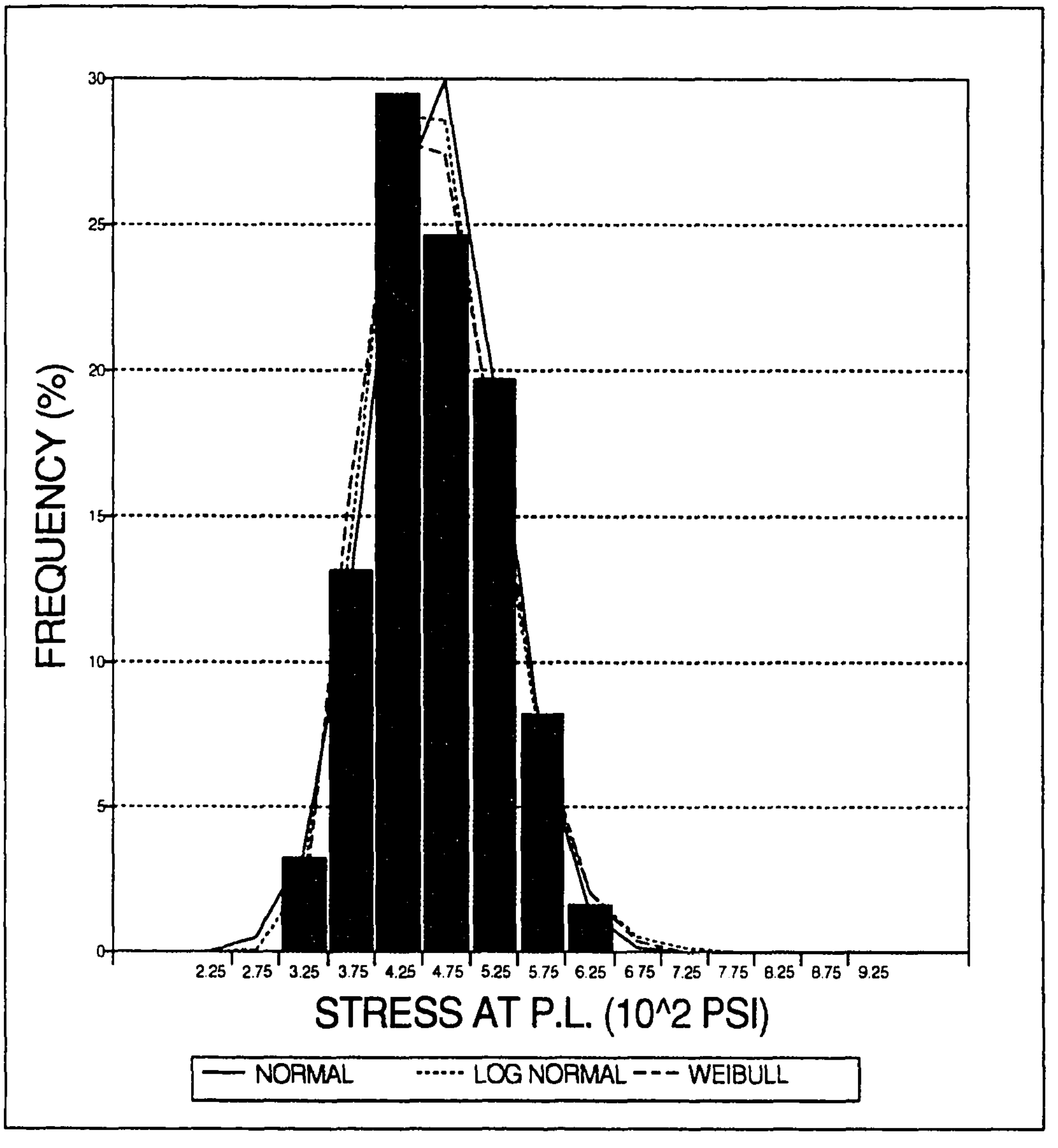


FIGURE C.10: PERPENDICULAR COMPRESSION
STRESS AT P.L. M.C.= 12%

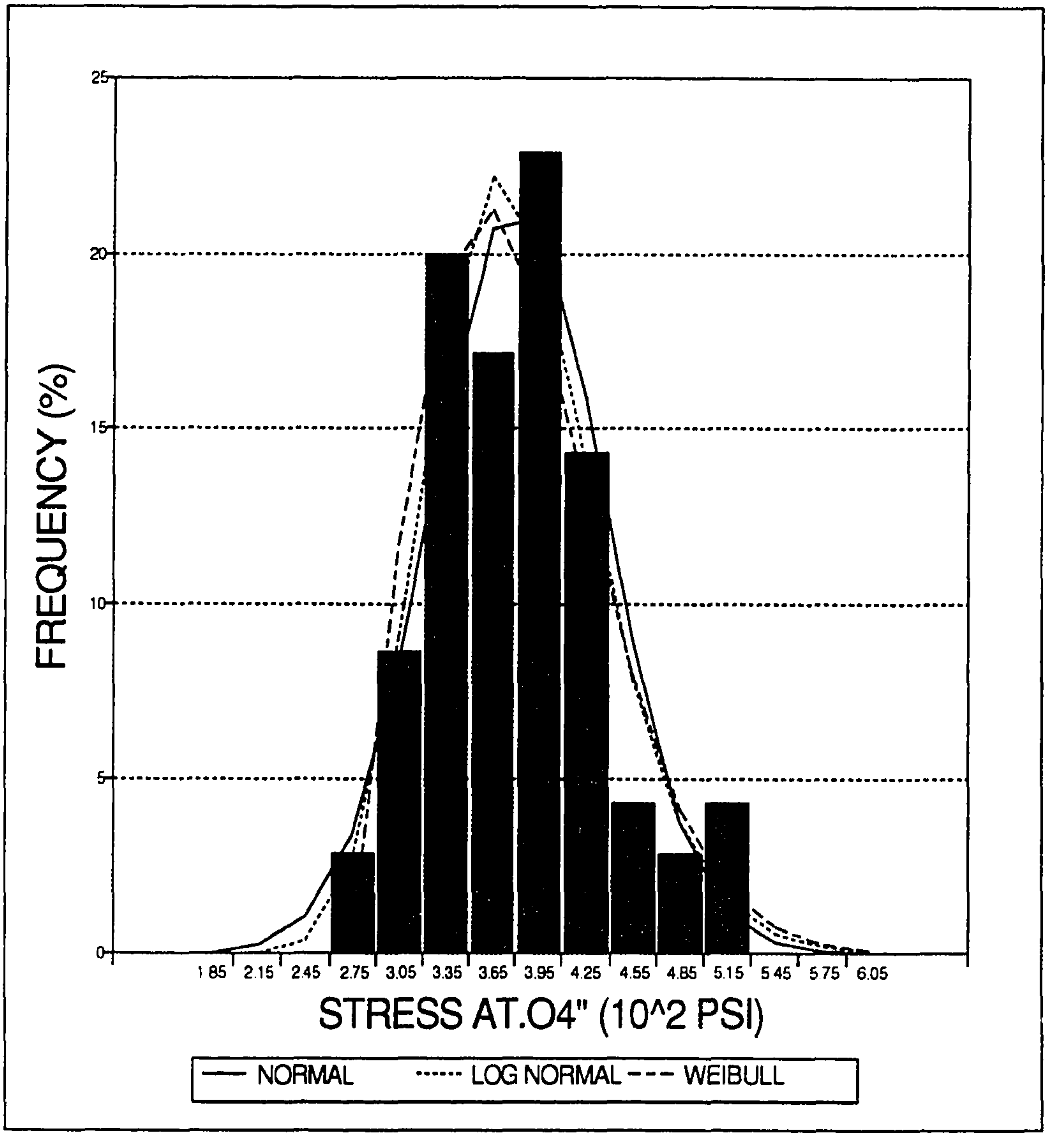


FIGURE C.11: PERPENDICULAR COMPRESSION
STRESS AT .04" GREEN WOOD

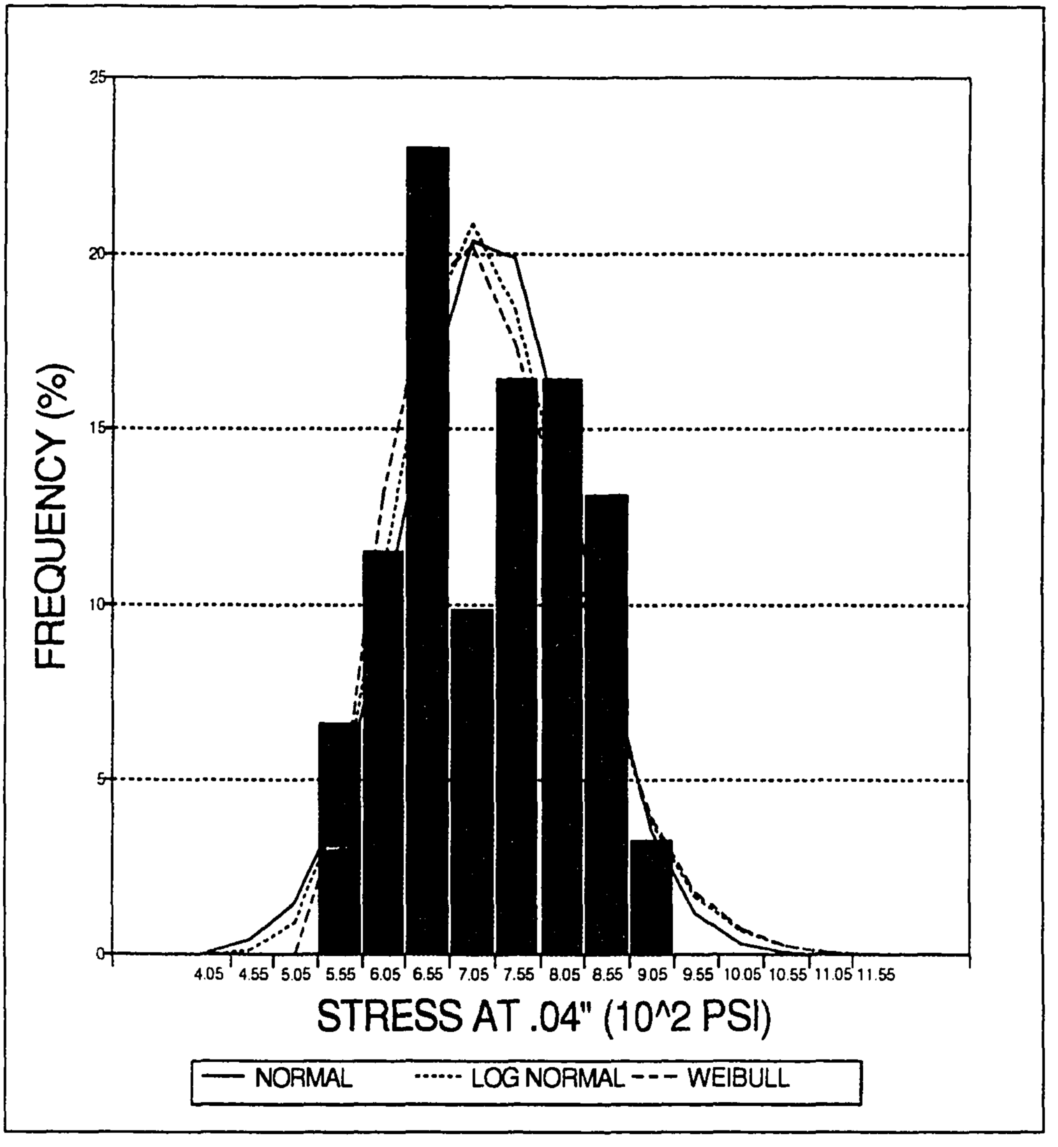


FIGURE C.12: PERPENDICULAR COMPRESSION STRESS AT .04" M.C. = 12%

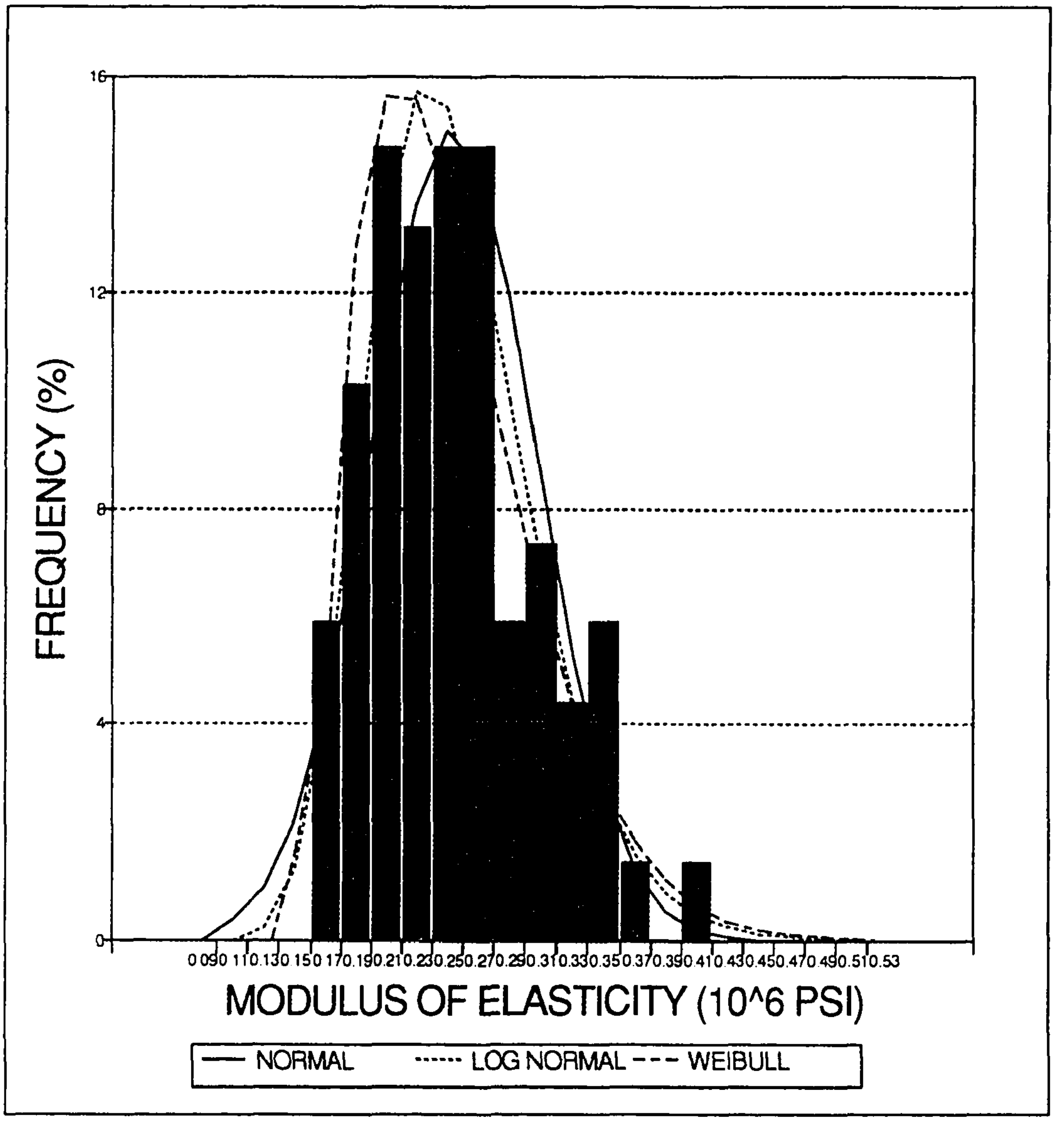


FIGURE C.13: PERPENDICULAR COMPRESSION
MODULUS OF ELASTICITY, GREEN WOOD

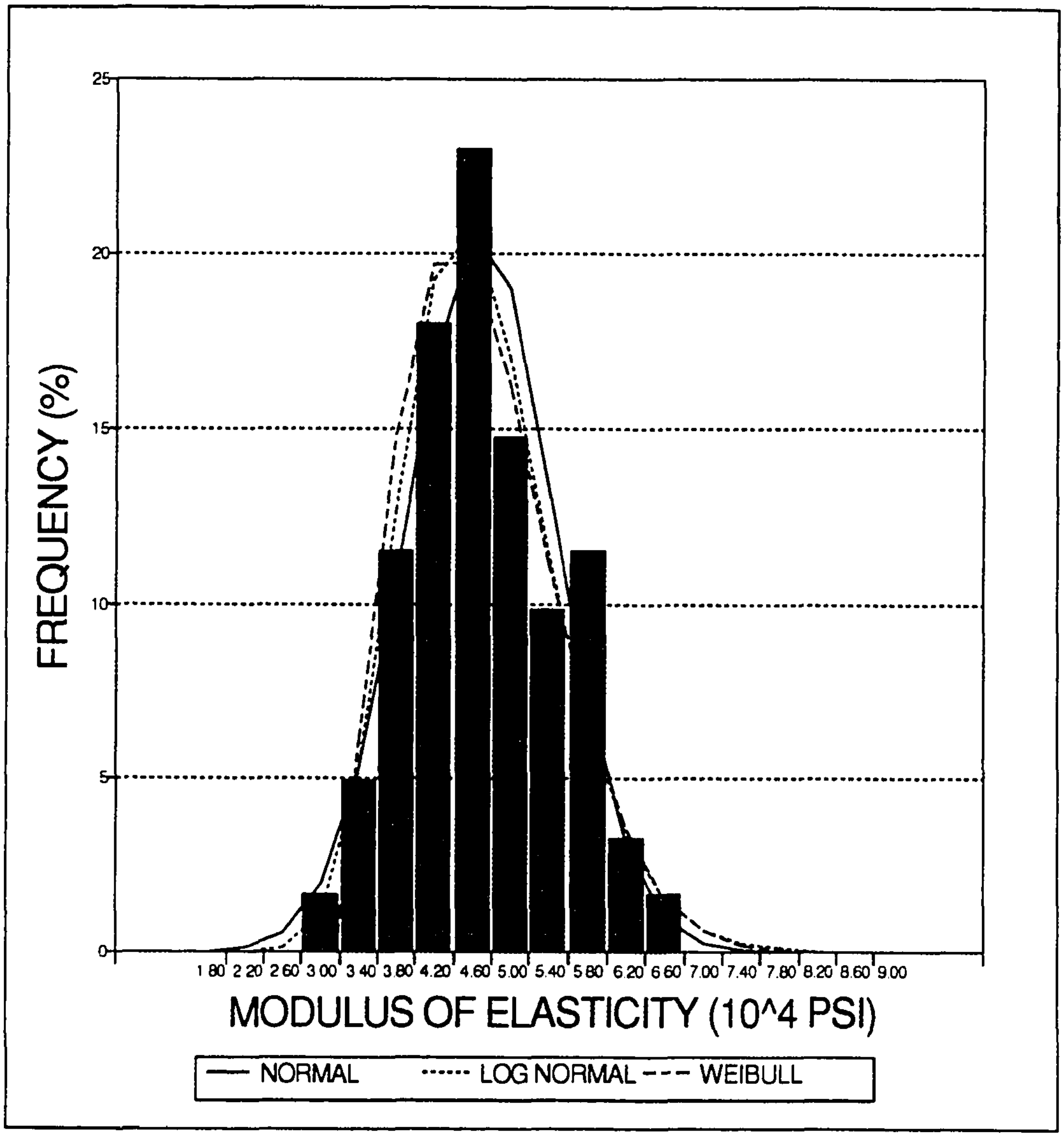


FIGURE C.14: PERPENDICULAR COMPRESSION
MODULUS OF ELASTICITY, M.C. = 12%

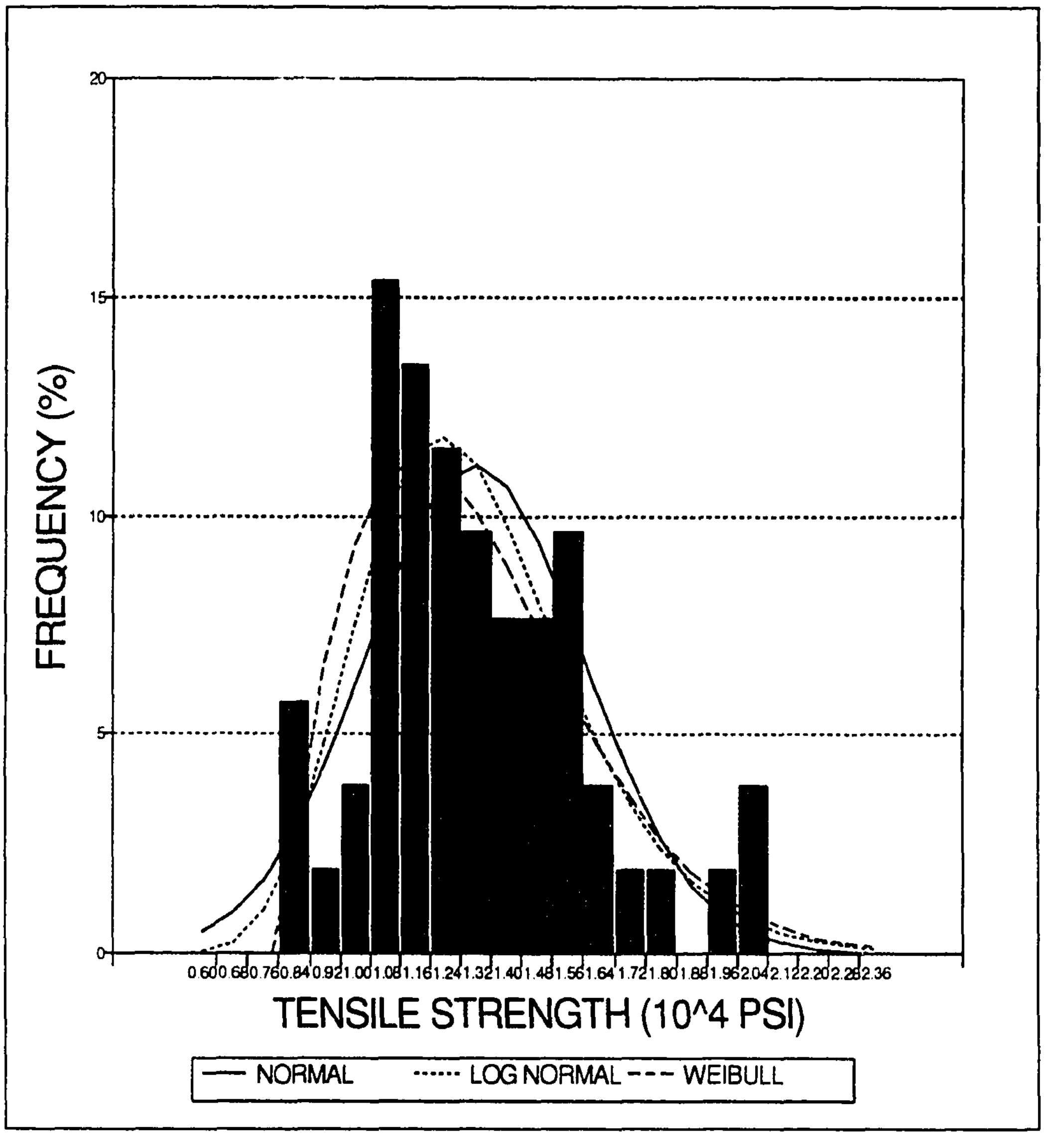


FIGURE C.15: PARALLEL TO GRAIN
TENSILE STRENGTH, M.C. = 12%

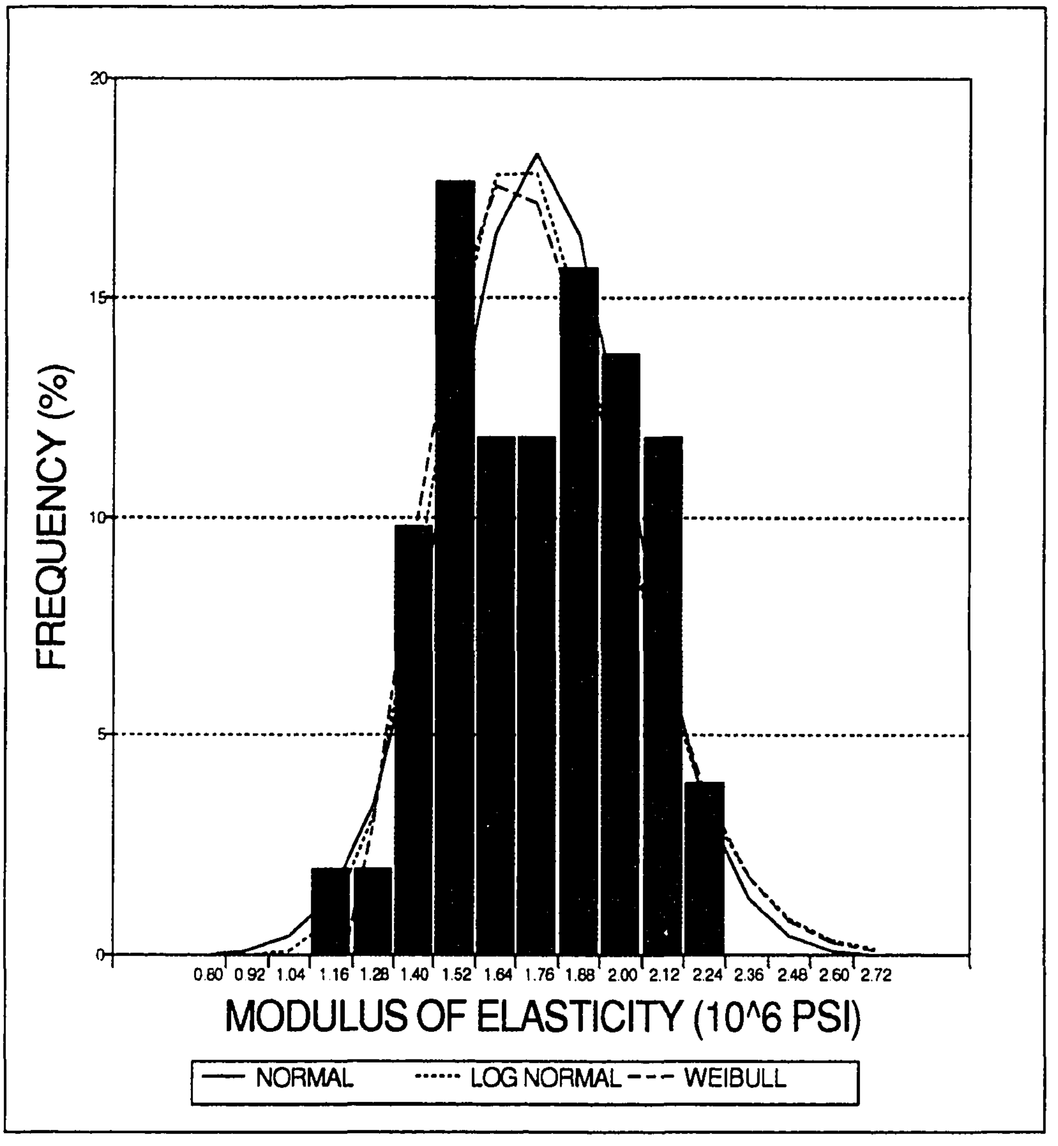


FIGURE C.16: PARALLEL TO GRAIN
TENSILE MODULUS OF ELASTICITY, M.C. = 12%

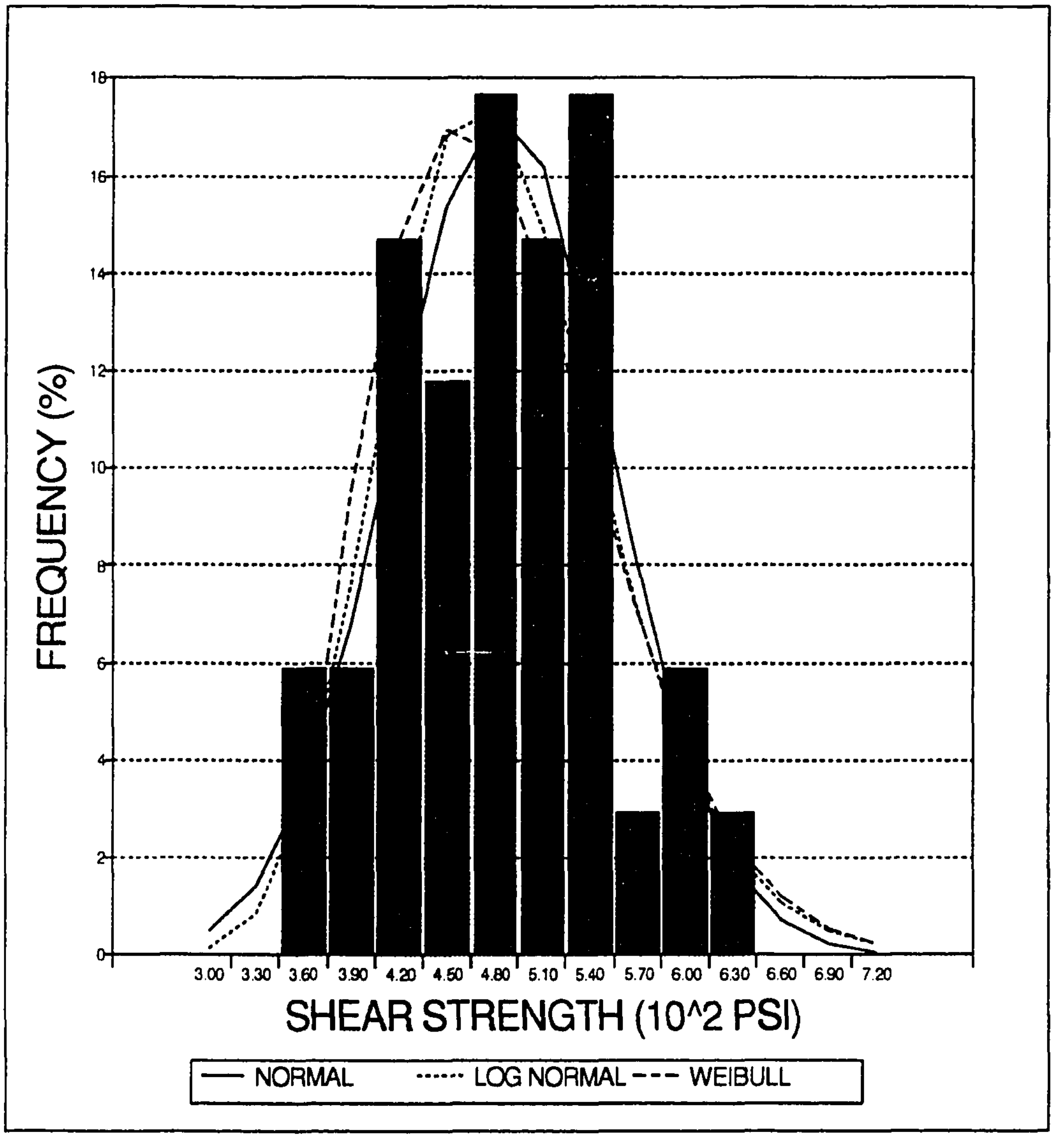


FIGURE C.17: PARALLEL TO GRAIN
SHEAR STRENGTH, GREEN WOOD

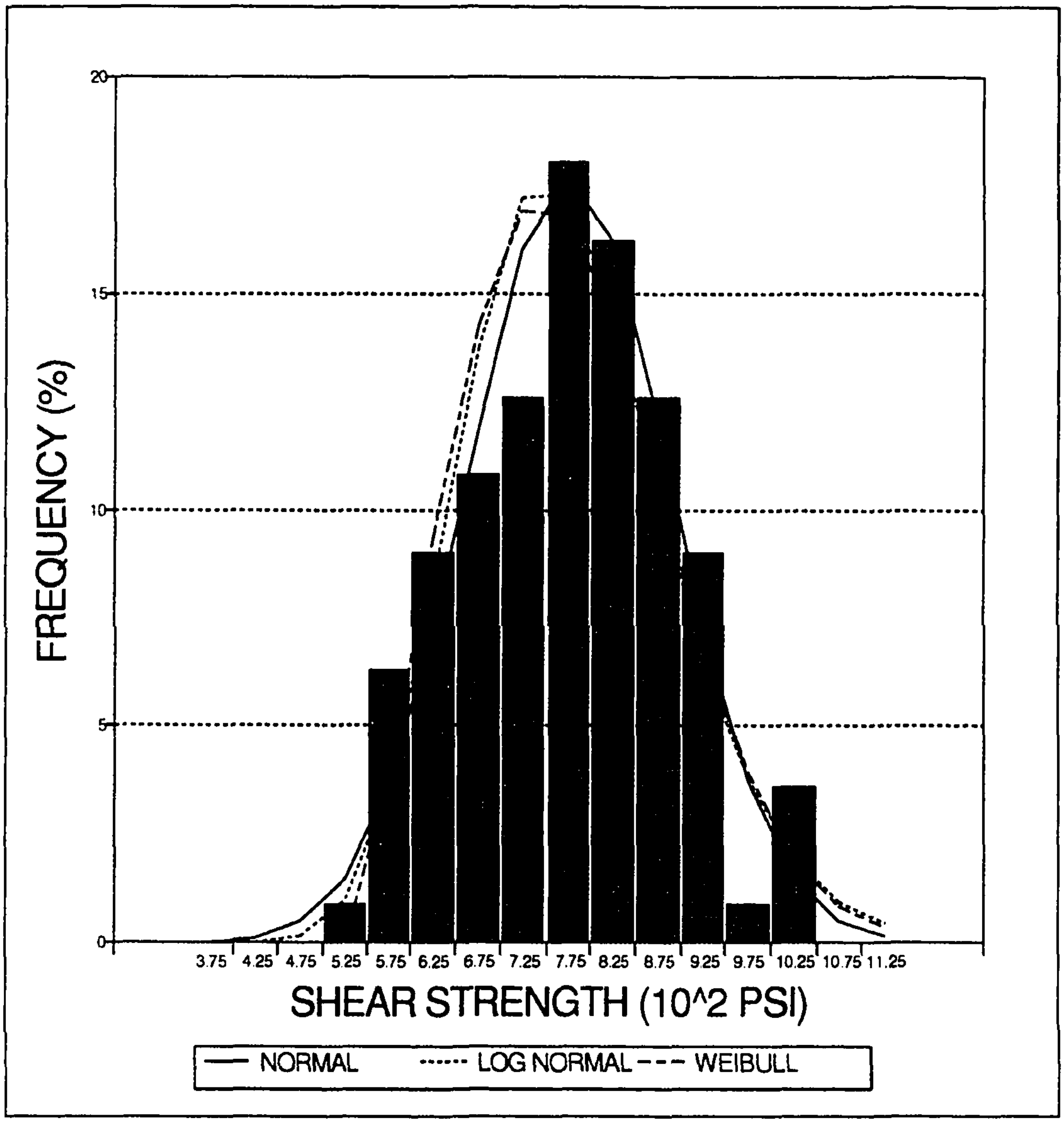


FIGURE C.18: PARALLEL TO GRAIN
SHEAR STRENGTH, M.C. = 12%

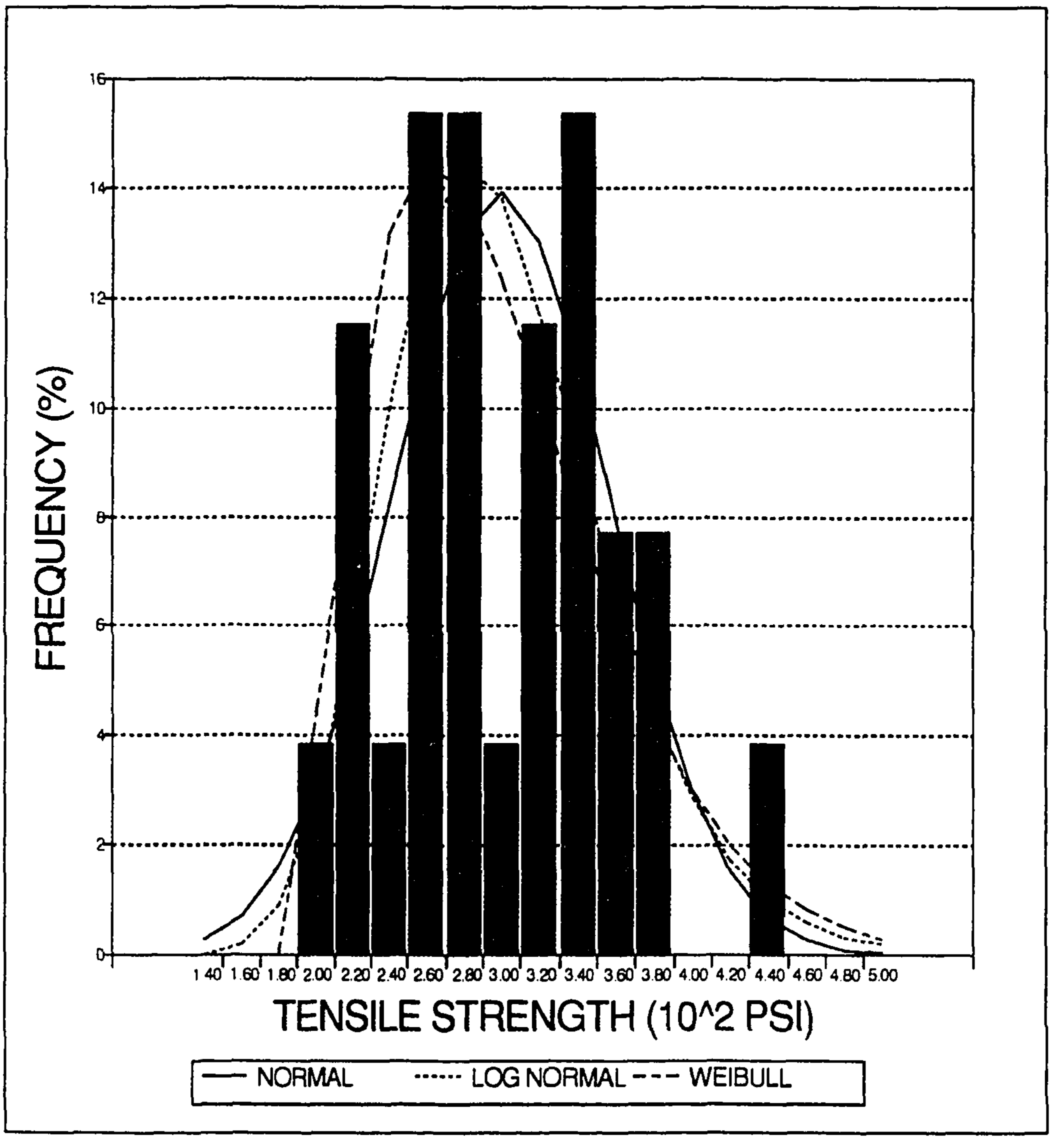


FIGURE C.19: PERPENDICULAR TO GRAIN
TENSILE STRENGTH, GREEN WOOD

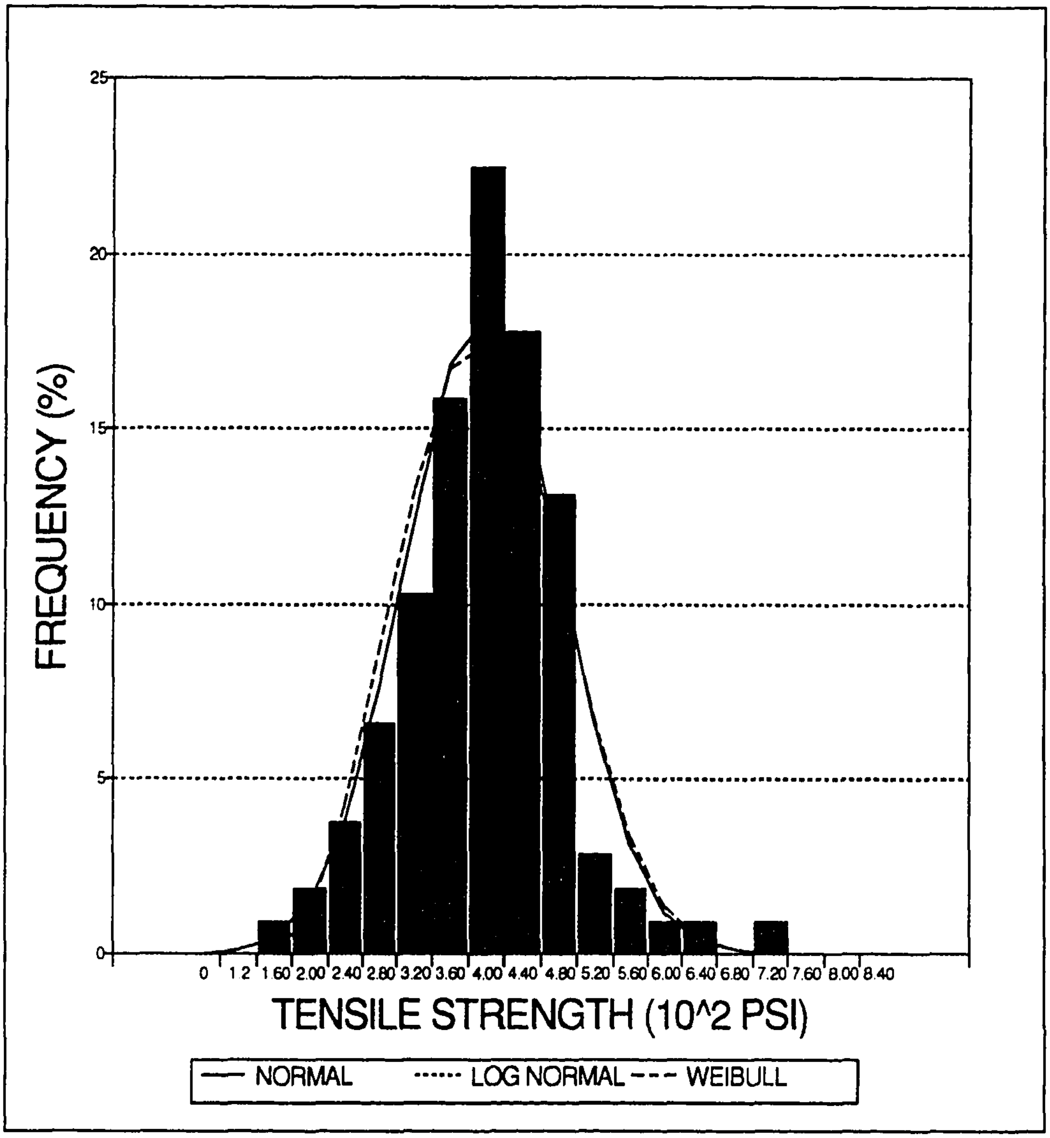


FIGURE C.20: PERPENDICULAR TO GRAIN
TENSILE STRENGTH, M.C. = 12%

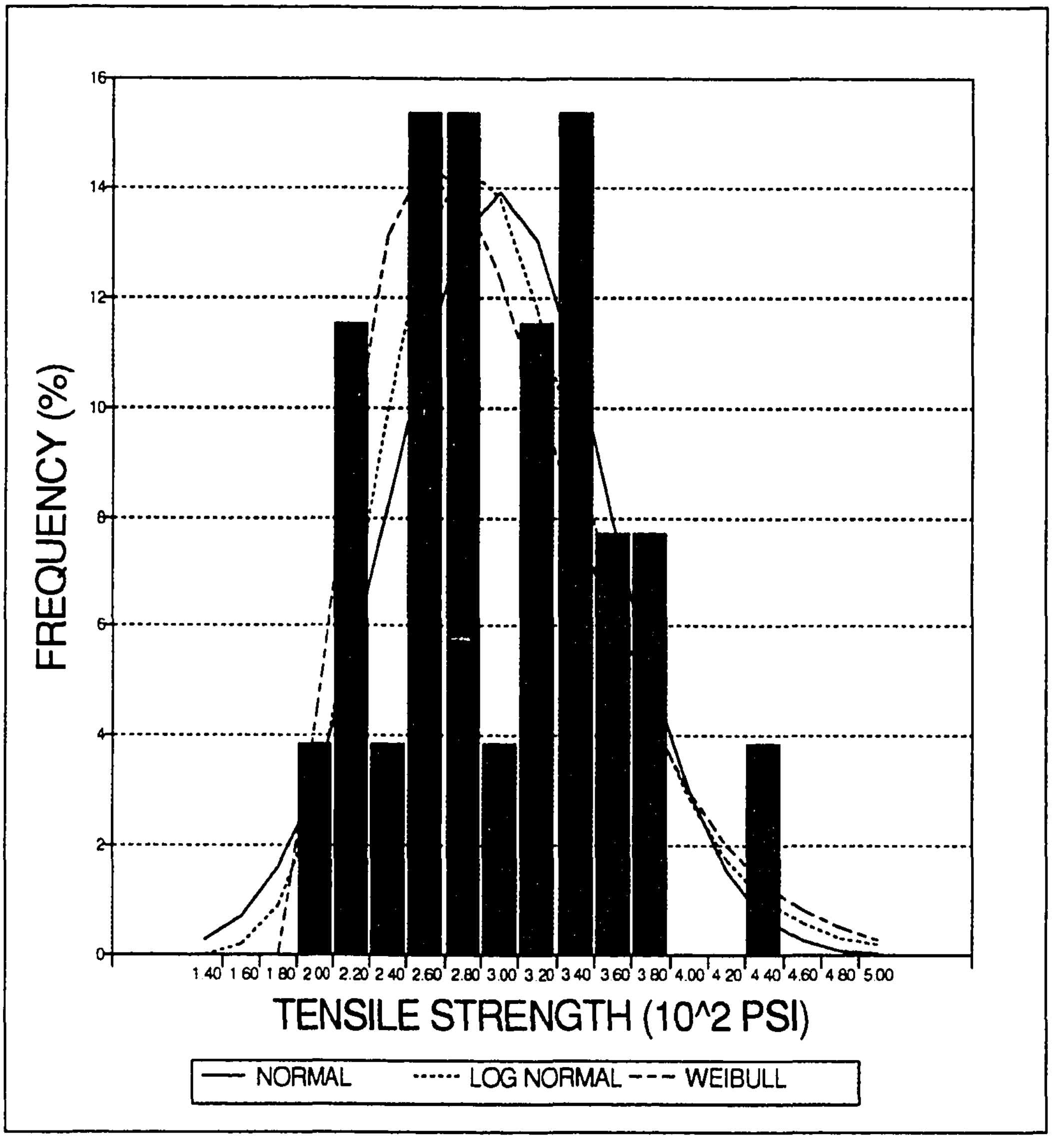


FIGURE C.21: CLEAVAGE LOAD, GREEN WOOD

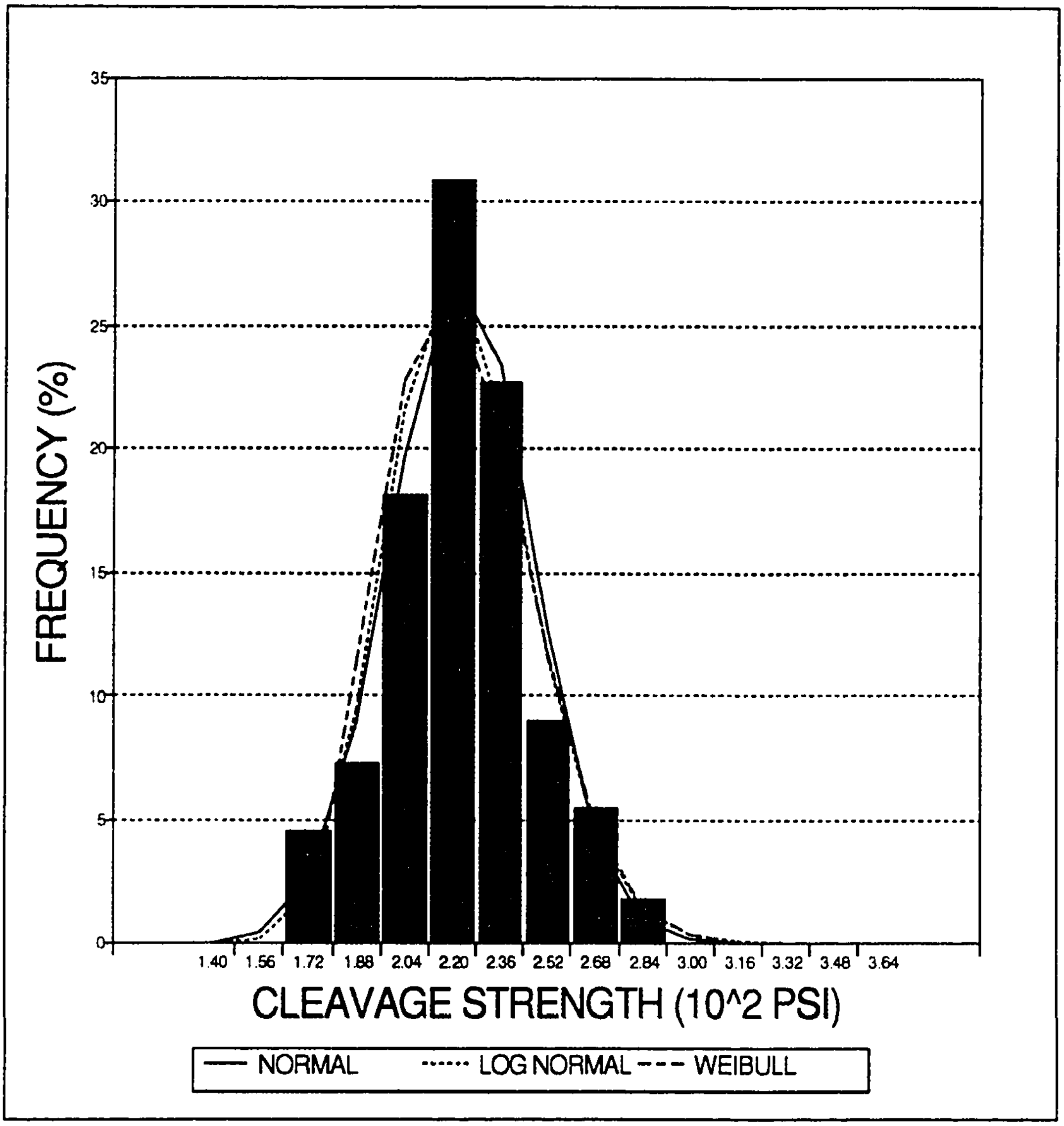


FIGURE C.22: CLEAVAGE LOAD, M.C. = 12%

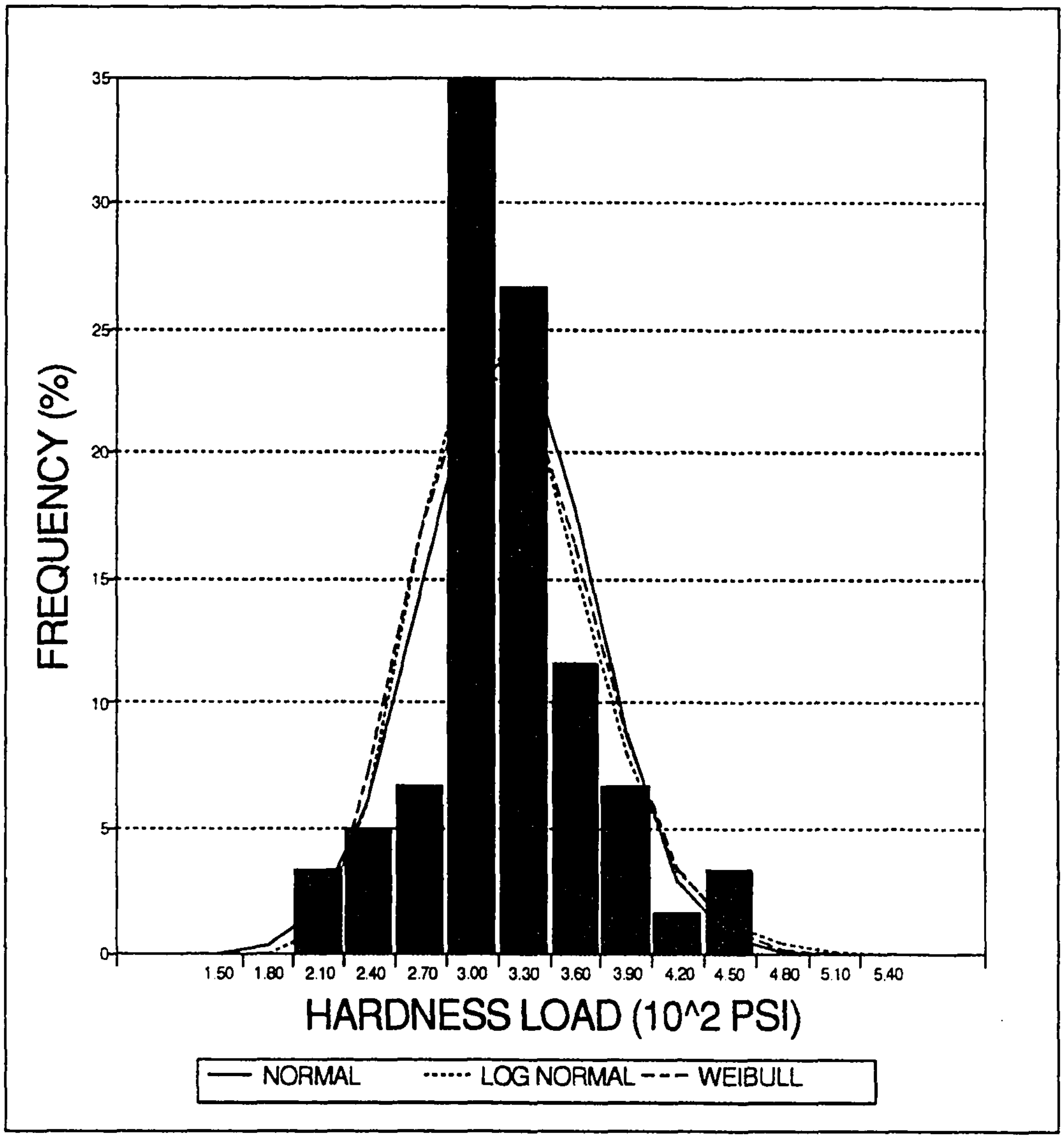


FIGURE C.23: RADIAL AND TANGENTIAL AVERAGE HARDNESS LOAD, GREEN WOOD

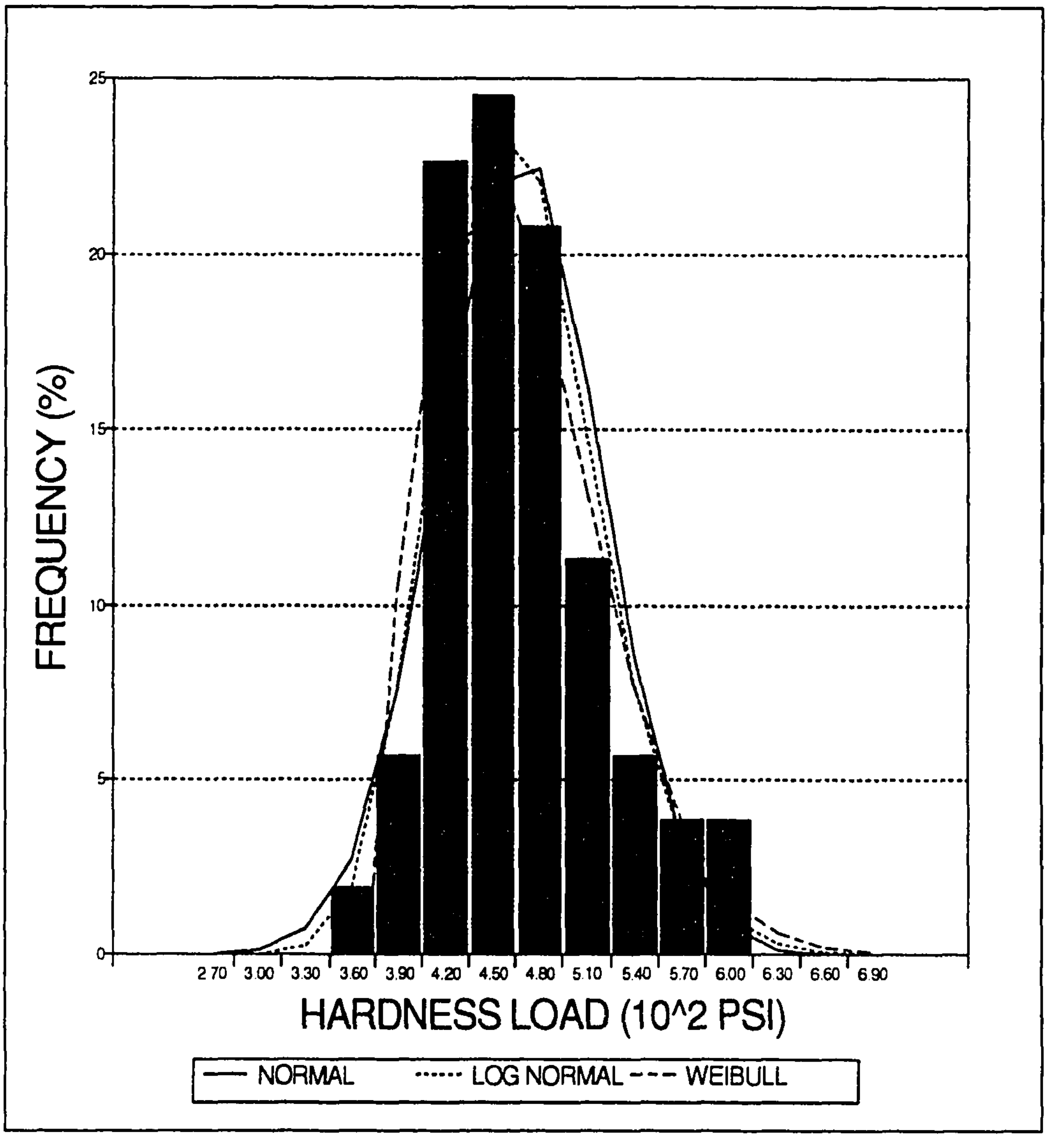


FIGURE C.24: RADIAL AND TANGENTIAL AVERAGE HARDNESS LOAD, M.C. = 12%

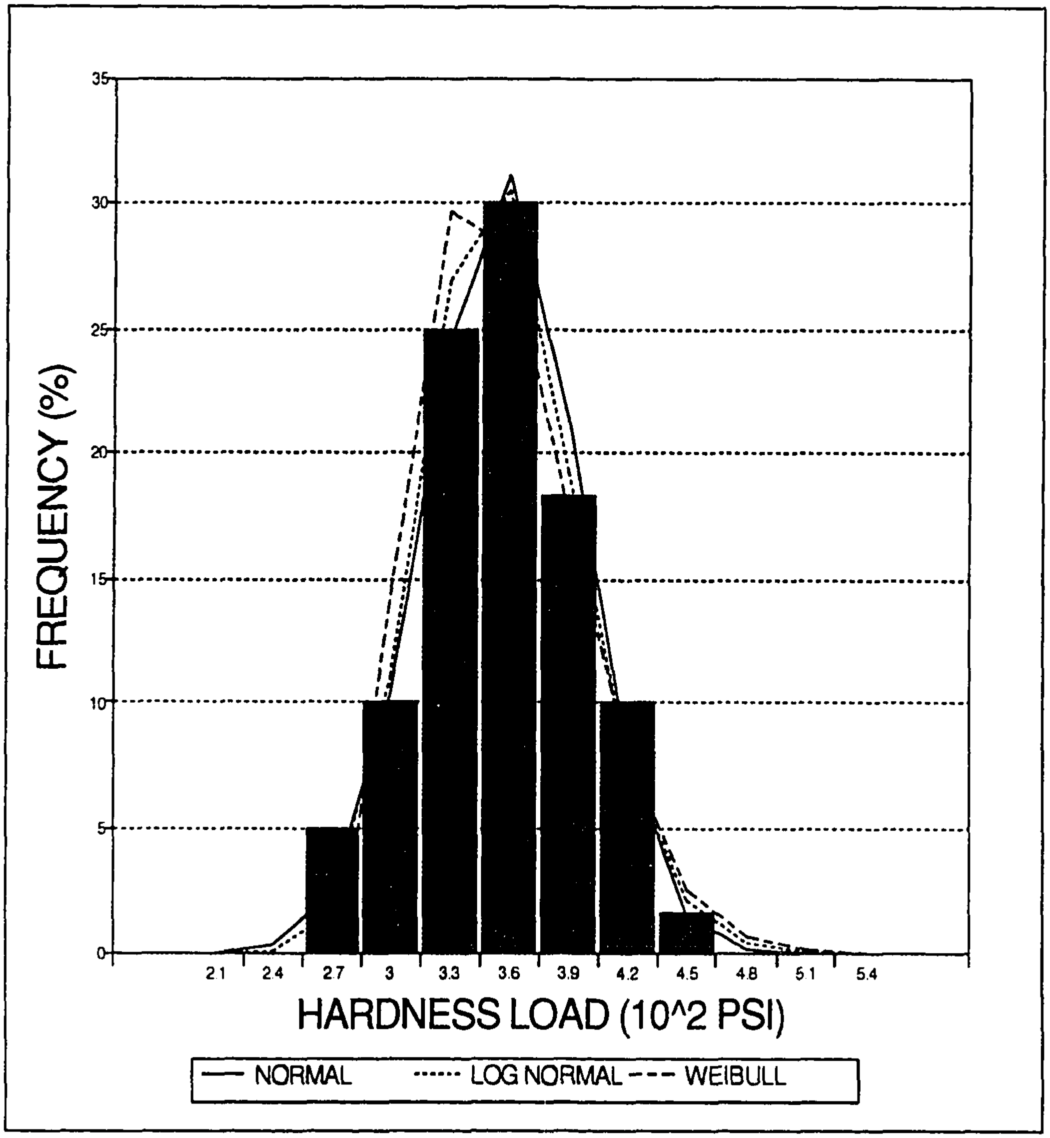


FIGURE C.25: END GRAIN
HARDNESS LOAD, GREEN WOOD

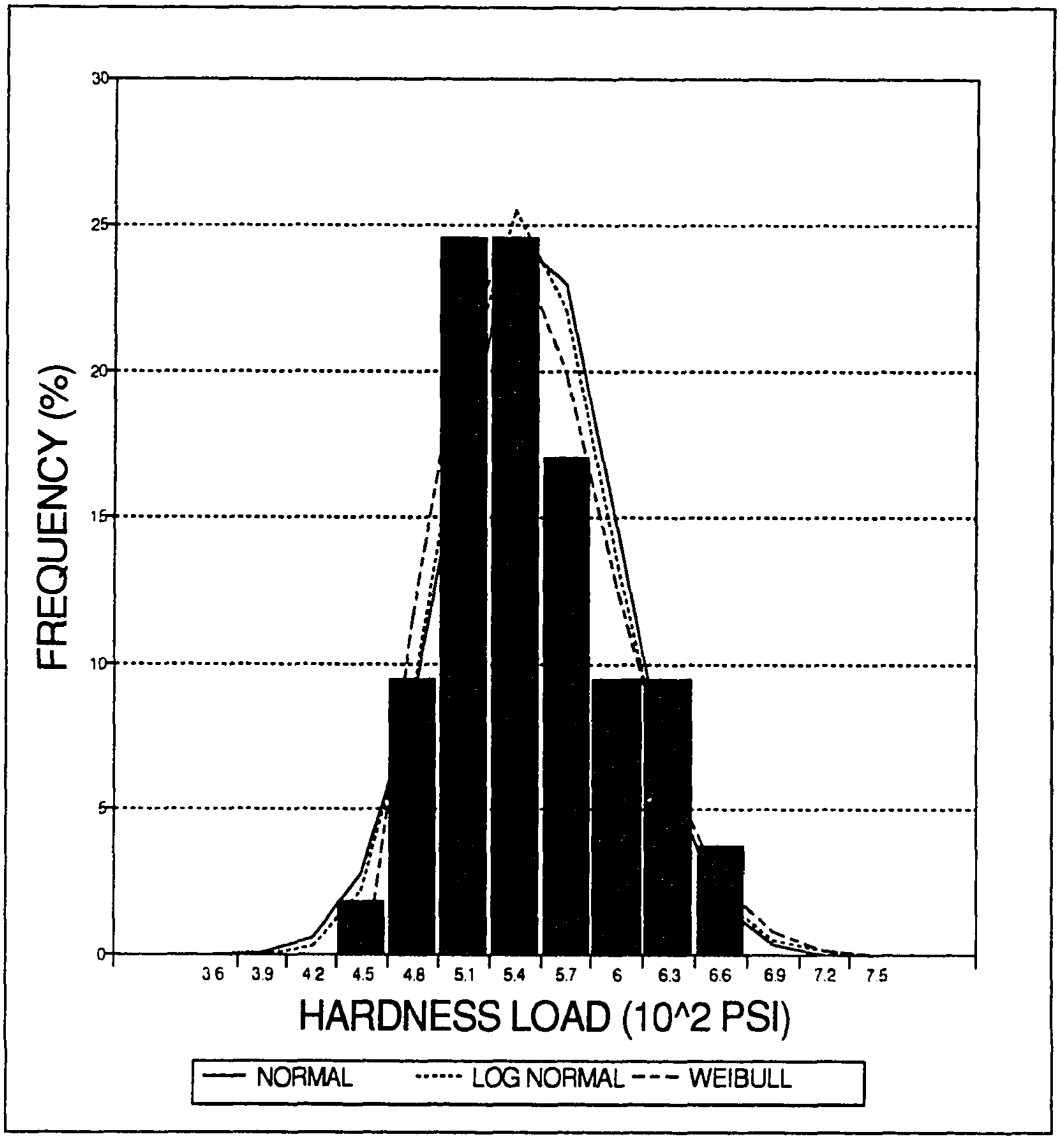


FIGURE C.26: END GRAIN
HARDNESS LOAD, M.C. = 12%

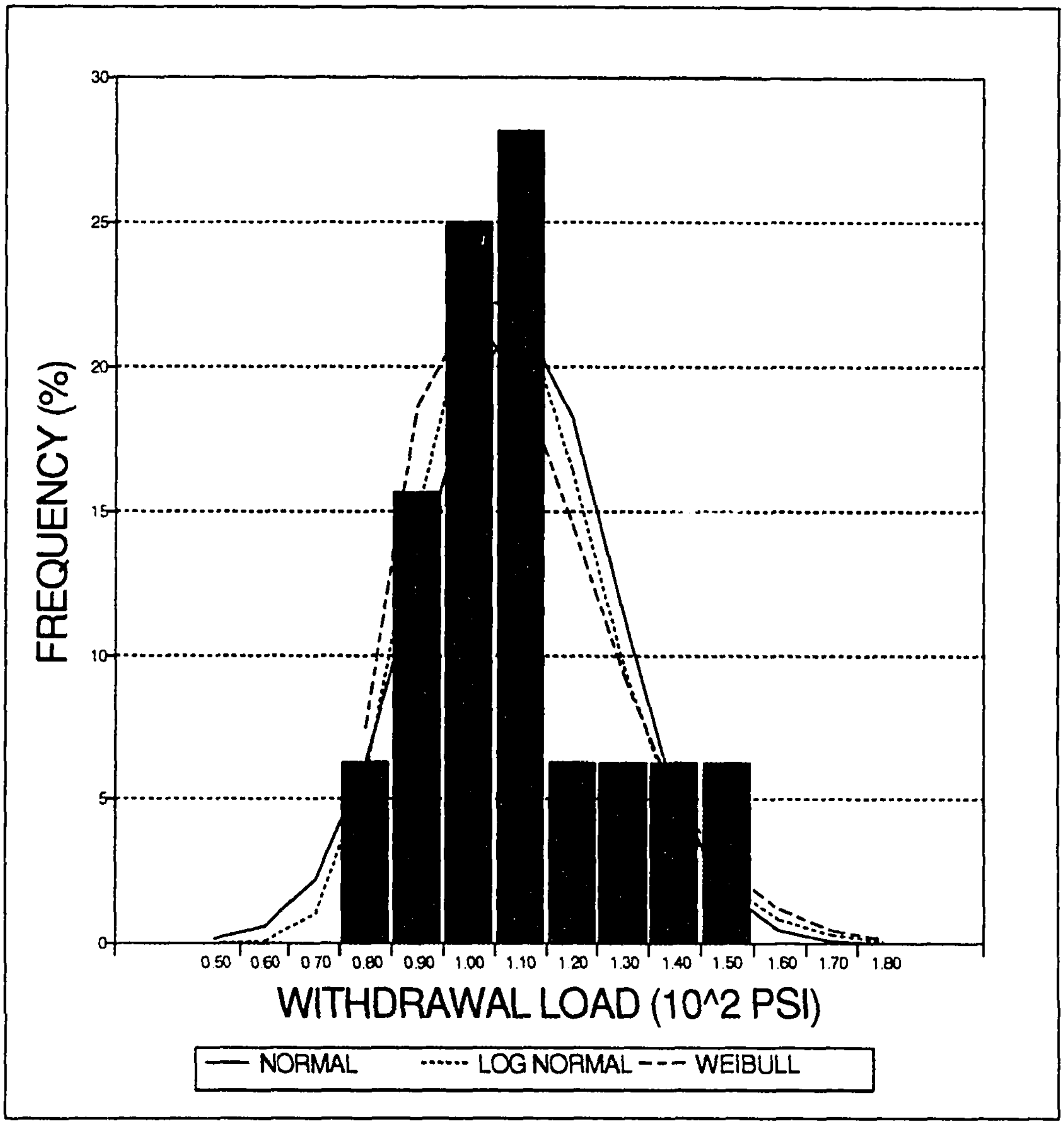


FIGURE C.27: RADIAL AND TANGENTIAL NAIL WITHDRAWAL LOAD, GREEN WOOD

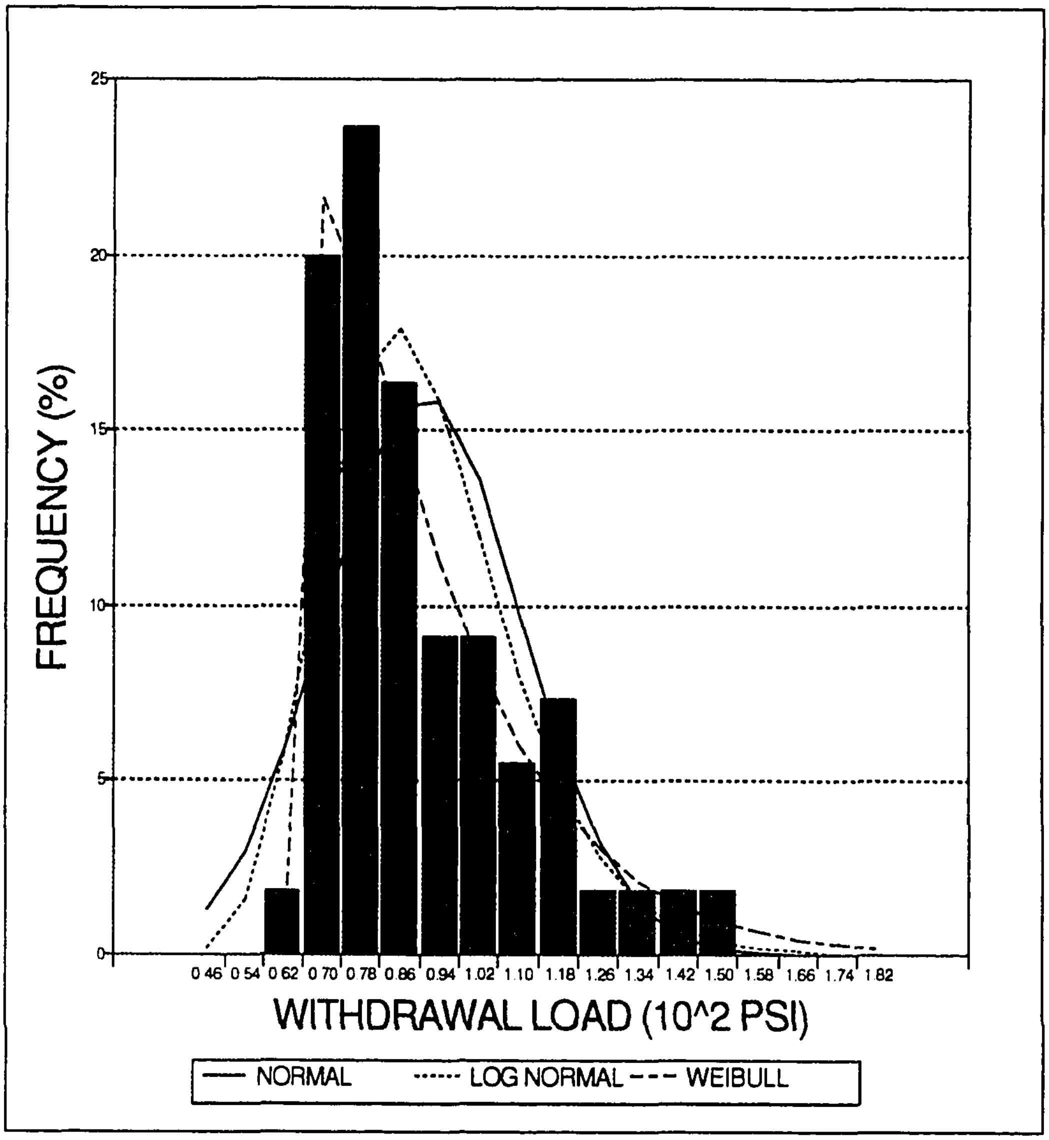


FIGURE C.28: RADIAL AND TANGENTIAL NAIL WITHDRAWAL LOAD, M.C. = 12%

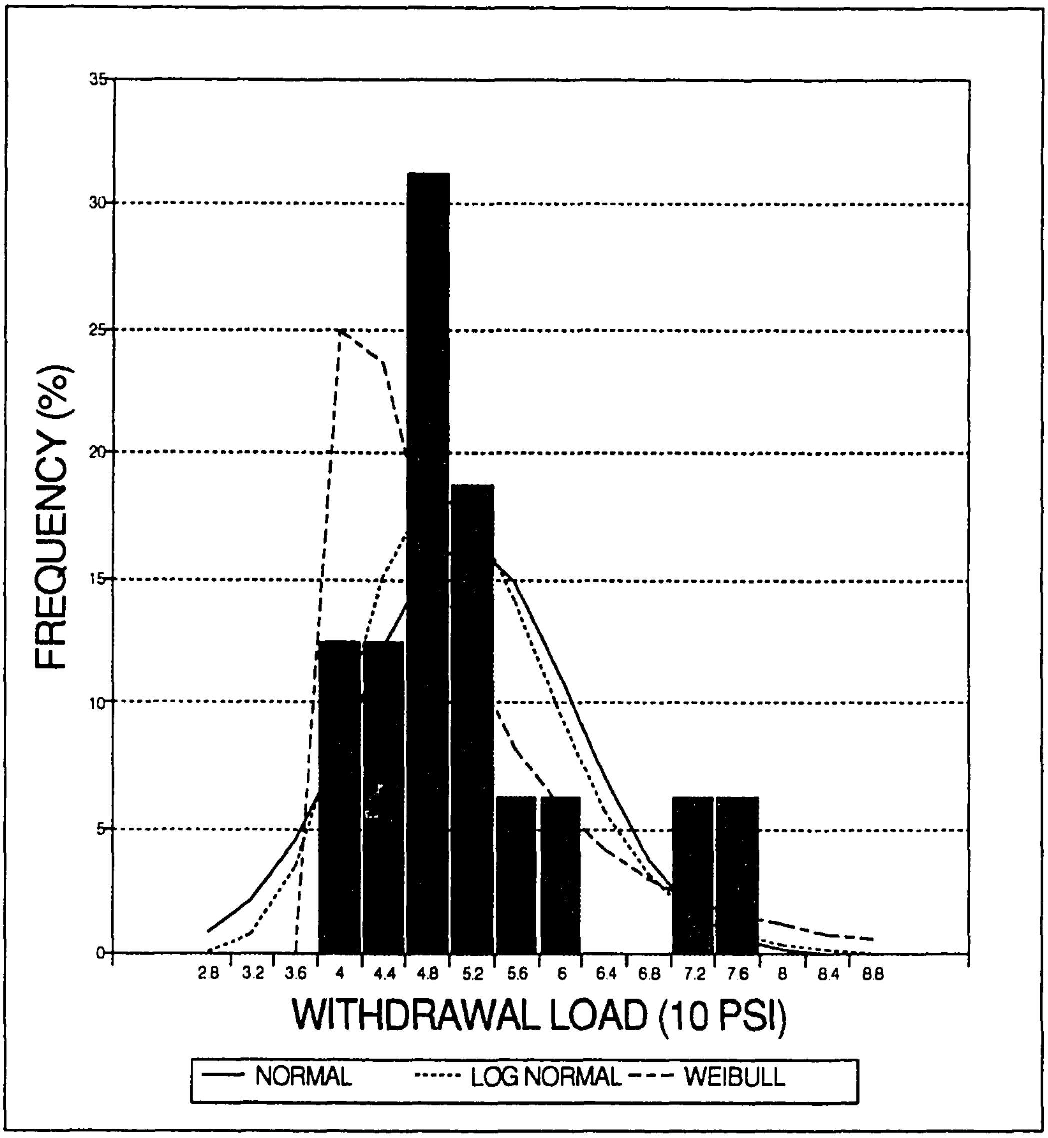


FIGURE C.29: END GRAIN
NAIL WITHDRAWAL LOAD, GREEN WOOD

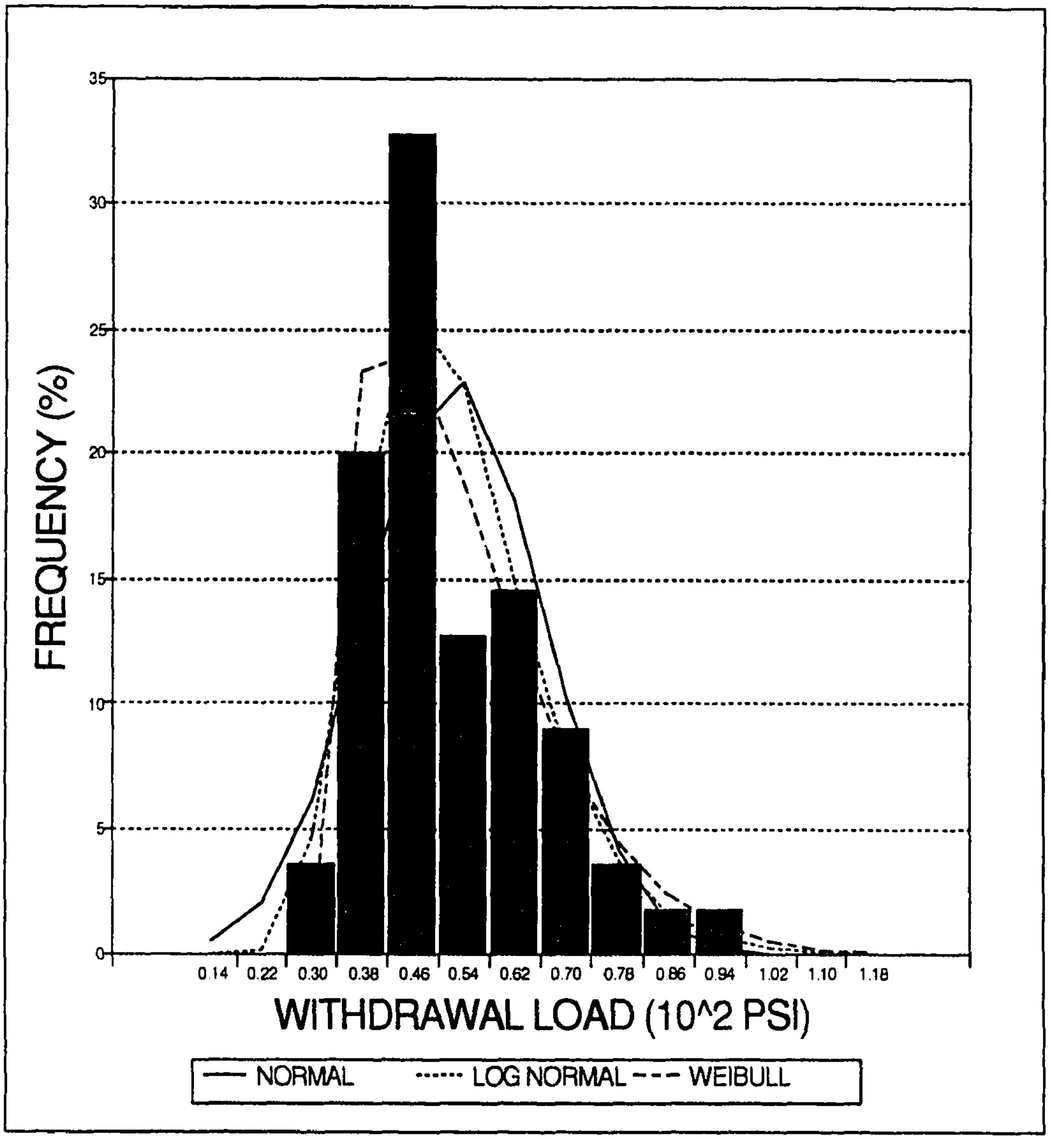


FIGURE C.30: END GRAIN
NAIL WITHDRAWAL, M.C. = 12%

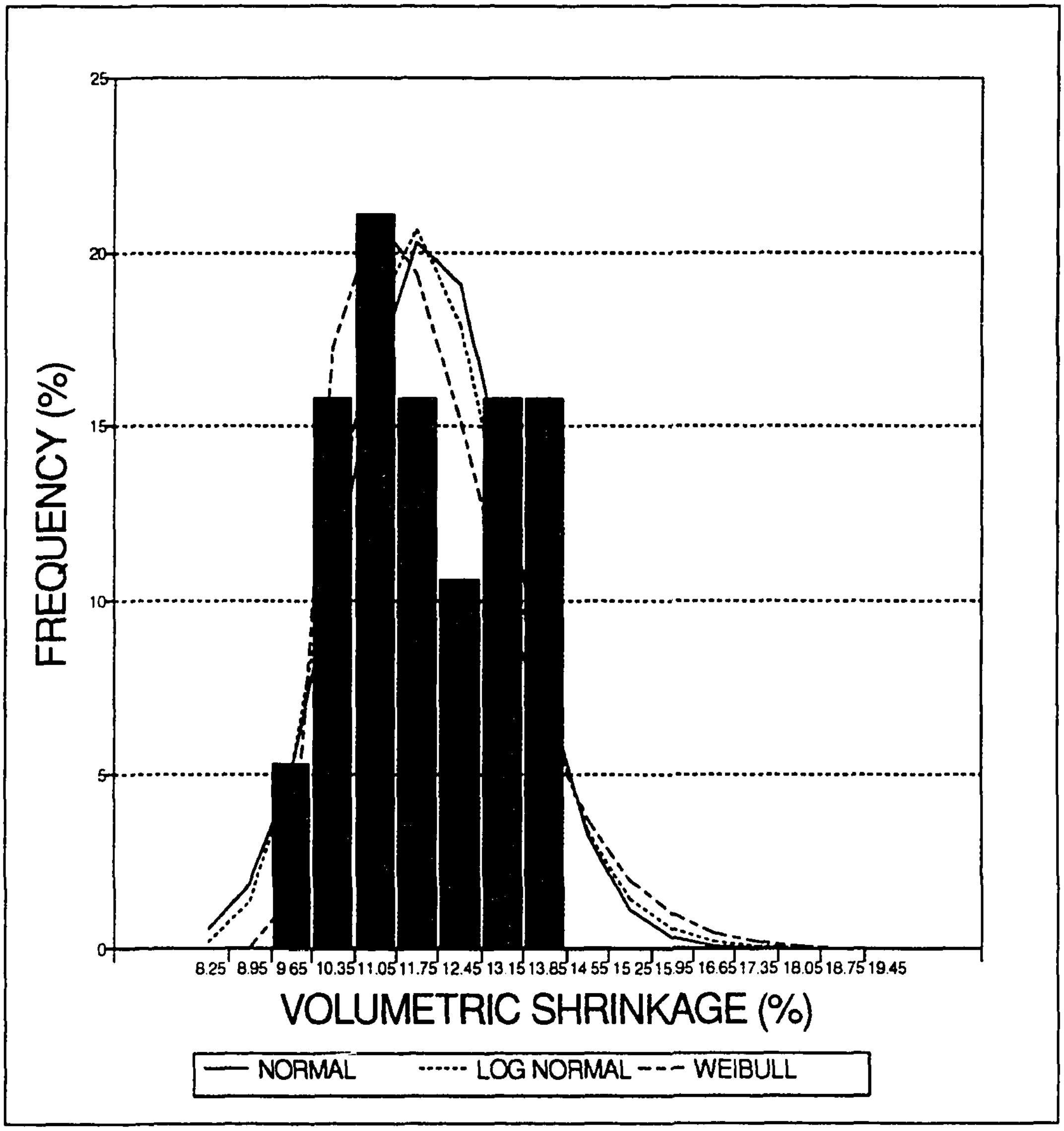


FIGURE C.31: VOLUMETRIC SHRINKAGE, GREEN WOOD

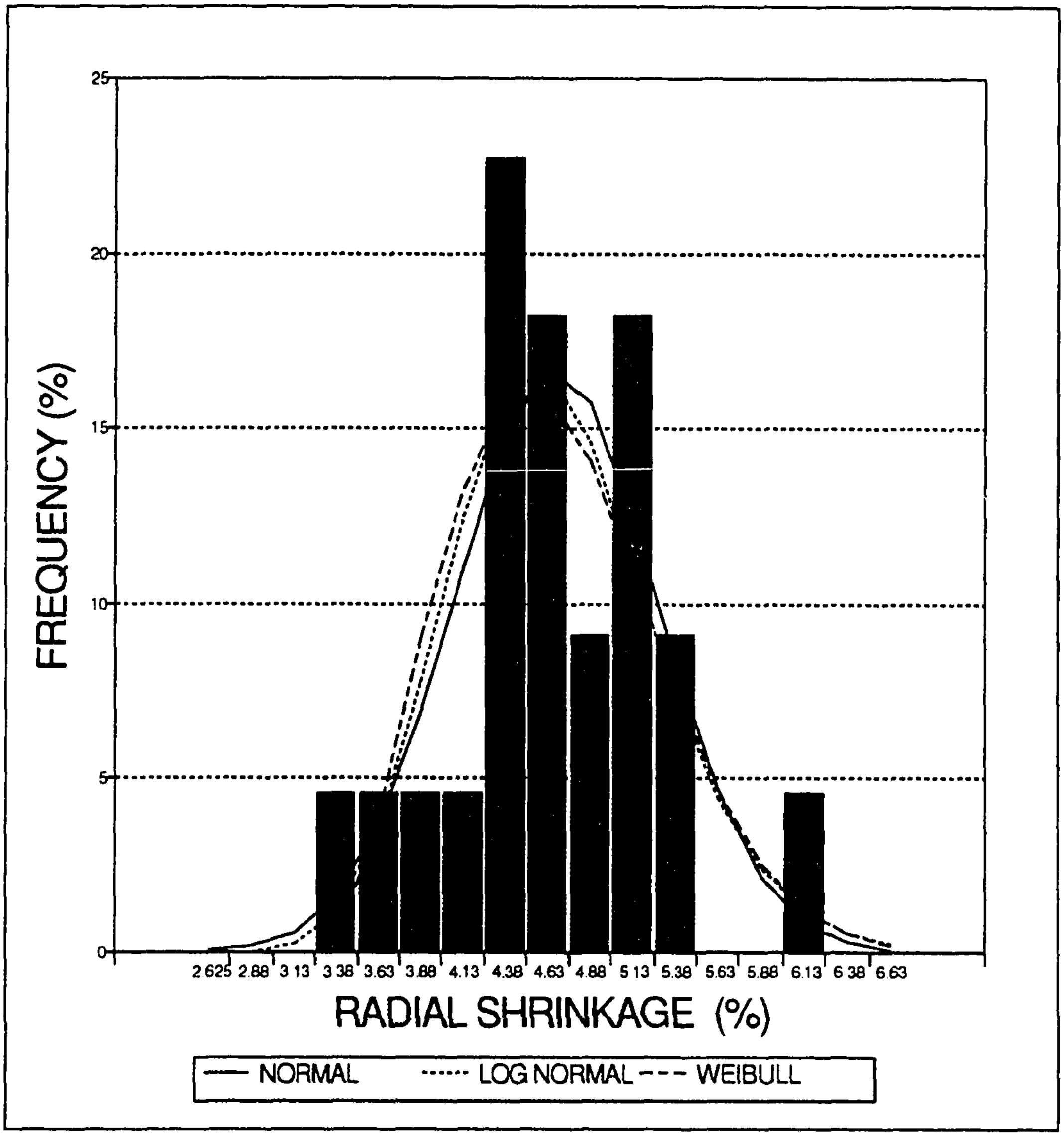


FIGURE C.32: RADIAL SHRINKAGE, GREEN WOOD

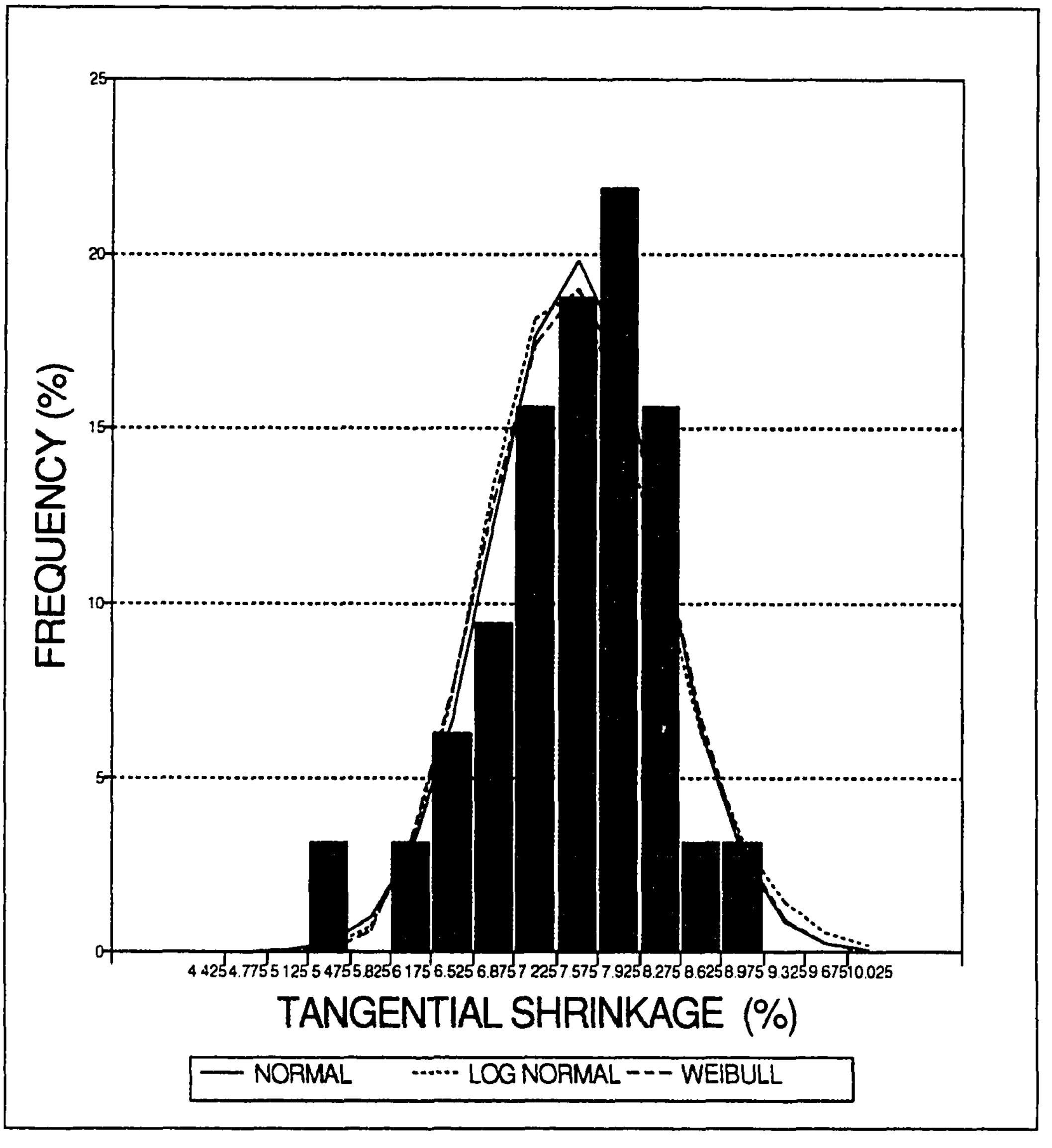


FIGURE C.33: TANGENTIAL SHRINKAGE, GREEN WOOD

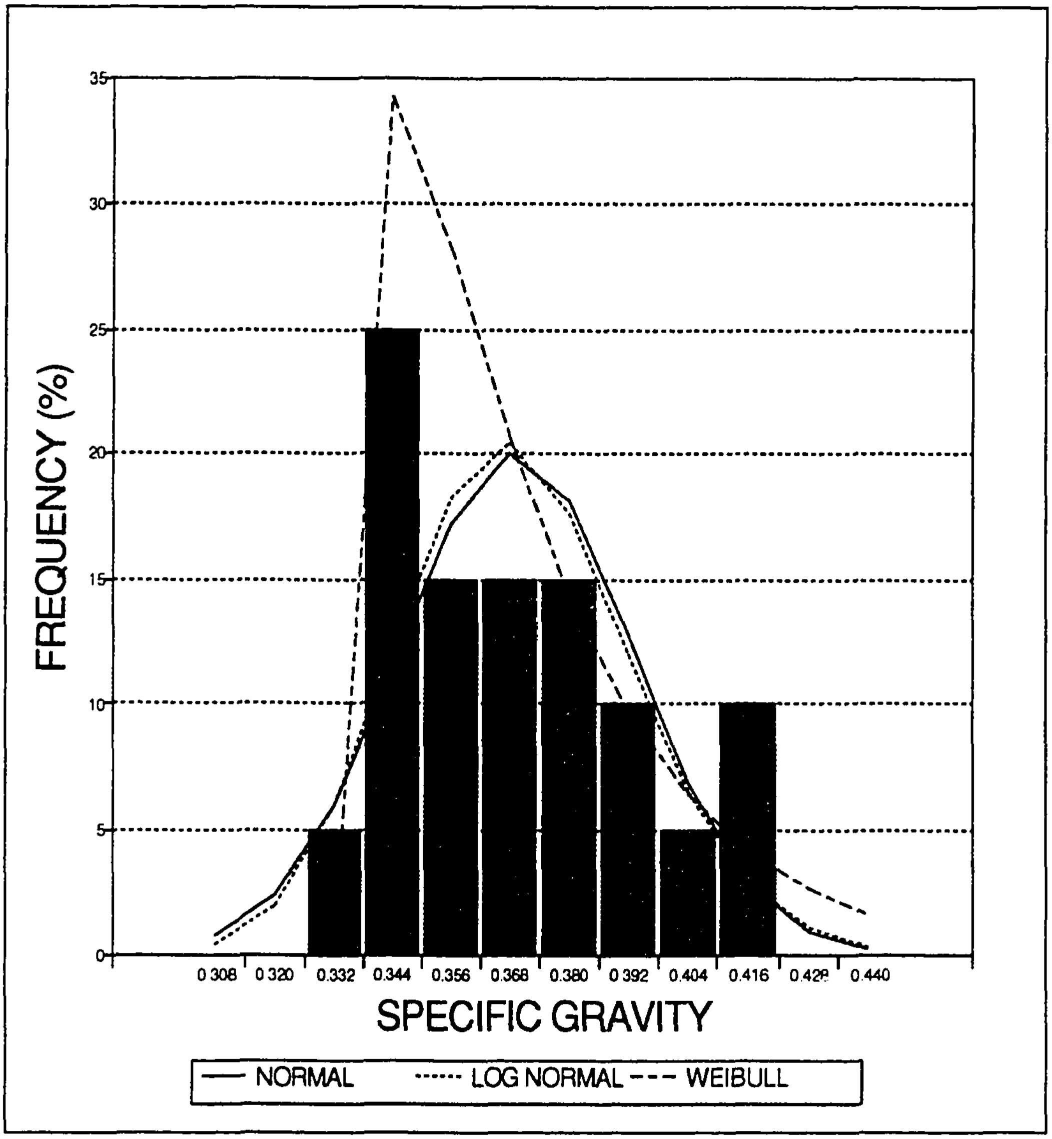


FIGURE C.34: SPECIFIC GRAVITY, GREEN WOOD

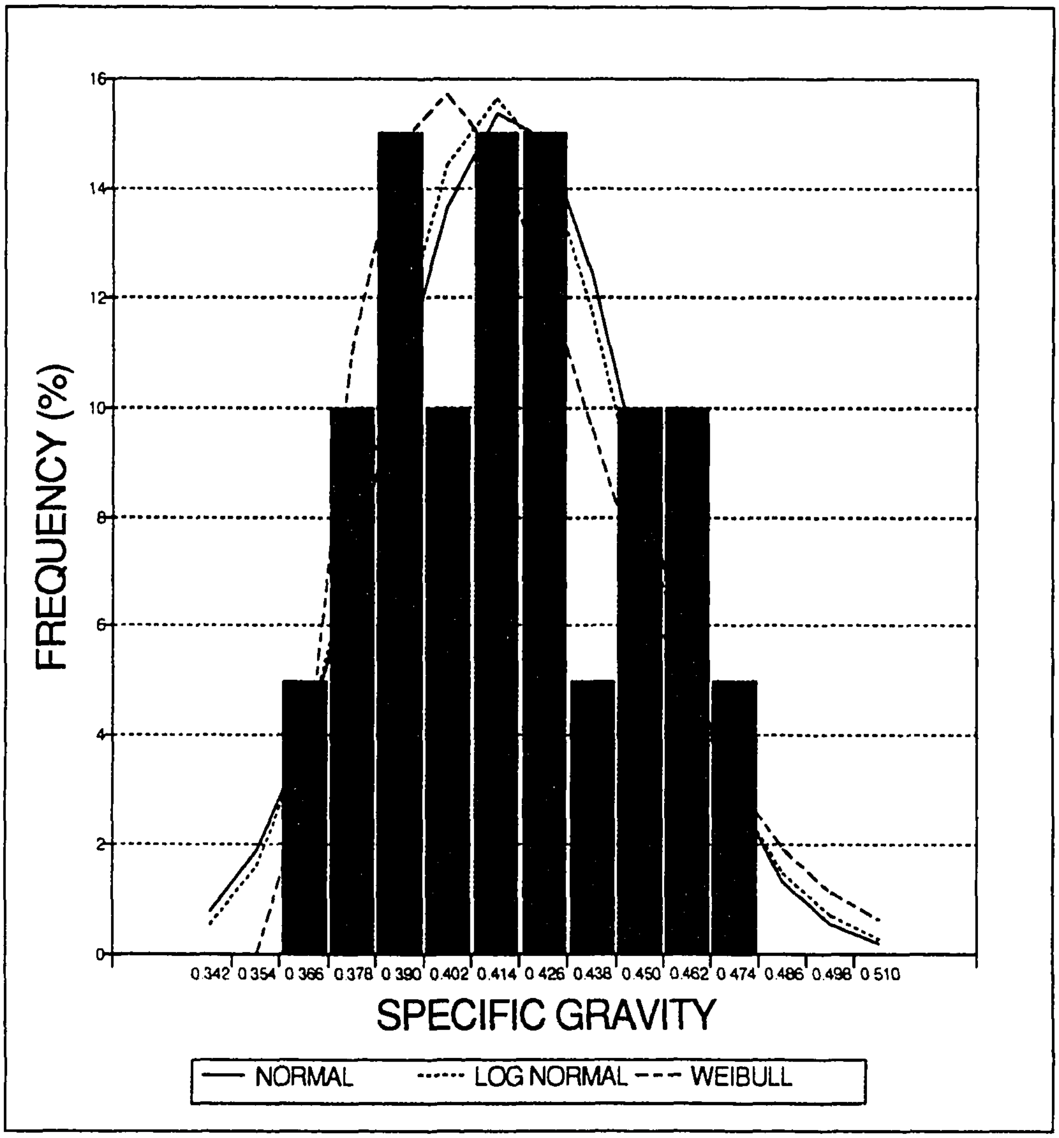


FIGURE C.35: SPECIFIC GRAVITY, M.C. = 12%

APPENDIX D: SUMMARY OF MECHANICAL PROPERTIES VALUES

The tables given in this appendix contain the results of the statistical analyses performed on the test data sets collected during this study, as described in Section 5.3. The tables list values for mean, 95% confidence limit, standard deviation, coefficient of variation (C.O.V.), the 5% exclusion limit, the 75% lower limit on the 5% exclusion limit, and the results of the χ^2 test. Units are also given for the table entries, along with the number of observations used in each of the analyses.

It is important to note that the values given in Tables D.1 through D.6 are the results of tests on small, clear samples. Thus, the results in this appendix represent the pure material strength of the wood, without defects, and should not be used as allowable design values for structural engineering. Allowable design values, obtained by applying corrections to the pure material properties given here are given in Section 5.5 and Appendix E.

The first three tables, Tables D.1 through D.3, contain the results of the analysis for the green wood data sets. Table D.1 contains values obtained using the normal distribution, while Table D.2 and Table D.3 are based on the log normal and Weibull distributions, respectively.

Tables D.4 through D.6 contain the results of the analysis performed on the seasoned wood data sets, for a moisture content of 12%. Table D.4 contains values obtained using the normal distribution, while Table D.5 is based on the log normal distribution and Table D.6 is based on the Weibull distribution.

TABLE D.1: NORMAL DISTRIBUTION, GREEN WOOD

TEST TYPE	UNITS	OBSERVATIONS	MEAN	95% CONFID. INTERVAL	STANDARD DEVIATION	C.O.V. %	5 % EXCLUSION LIMIT	75% LOWER LIMIT	χ^2
STATIC BENDING									
MODULUS OF RUPTURE	(PSI)	164	5281.8	±76.3	494.2	9.3	4468.8	4426.3	15.1
MODULUS OF ELASTICITY	(PSI)	164	1180053	±21030	136119	11.5	956137	944873	4.6
PARALLEL COMPRESSION									
COMPRESSIVE STRENGTH	(PSI)	74	2802.3	±62.1	267.7	9.6	2361.8	2328.3	44.5
MODULUS OF ELASTICITY	(PSI)	74	1287293	±74430	320823	24.9	759540	719338	29.5
PERPEND. COMPRESSION									
STRESS AT P.L.	(PSI)	68	241.3	±10.6	43.7	18.1	169.4	160.0	27.1
STRESS AT .04"	(PSI)	68	381.5	±13.4	55.2	14.5	290.6	278.7	15.0
MODULUS OF ELASTICITY	(PSI)	68	25333	±1284	5302	20.9	16611	15468	22.5
PARALLEL TENSION									
TENSILE STRENGTH	(PSI)	0	---	---	---	---	---	---	---
MODULUS OF ELASTICITY	(PSI)	0	---	---	---	---	---	---	---
SHEAR STRENGTH (AVERAGE)	(PSI)	34	484.4	±24.1	68.9	14.2	371.0	349.5	13.5
PERP. TENSILE STRENGTH	(PSI)	26	299.2	±23.1	57.3	19.2	204.9	192.3	44.6
CLEAVAGE LOAD PER INCH	(LBS)	56	141.3	±3.05	11.4	8.1	122.5	120.9	15.0
HARDNESS									
RAD AND TAN AVG.	(LBS)	60	320.6	±12.31	48.1	15.0	241.4	234.7	26.8
END	(LBS)	60	356.7	±9.8	38.3	10.7	293.6	288.3	4.3
NAIL WITHDRAWAL									
RAD AND TAN AVG.	(LBS)	16	109.1	±9.7	18.3	16.8	79.0	70.0	29.3
END	(LBS)	16	51.5	±5.1	9.6	18.6	35.6	32.9	105
SHRINKAGE									
VOLUMETRIC	(%)	19	11.9	±.67	1.4	11.8	9.69	9.08	24.9
RADIAL	(%)	22	4.67	±.27	.60	12.8	3.69	3.44	44.2
TANGENTIAL	(%)	32	7.58	±.26	.72	9.5	6.40	6.16	34.8
SPECIFIC GRAVITY		20	.369	±.01	.023	6.2	.331	.321	43.2

TABLE D.2: LOG NORMAL DISTRIBUTION, GREEN WOOD

TEST TYPE	UNITS	OBSERVATIONS	MEAN	95% CONFID. INTERVAL	STANDARD DEVIATION	C.O.V. %	55 EXCLUSION LIMIT	75% LOWER LIMIT	χ^2
STATIC BENDING									
MODULUS OF RUPTURE	(PSI)	164	5281.81	±76.0	492.1	9.3	4513.1	4470.1	11.1
MODULUS OF ELASTICITY	(PSI)	164	1180087	±21193	137174	11.6	968800	959557	4.6
PARALLEL COMPRESSION									
COMPRESSIVE STRENGTH	(PSI)	74	2802.2	±61.7	266.0	9.5	2387.2	2359	17.3
MODULUS OF ELASTICITY	(PSI)	74	1291615	±85862	370098	28.7	782196	755142	55.6
PERPEND. COMPRESSION									
STRESS AT P.L.	(PSI)	68	241.3	±10.2	42.3	17.5	178.4	169.3	10.4
STRESS AT .04"	(PSI)	68	381.5	±13.3	55.0	14.4	298.2	286.3	9.8
MODULUS OF ELASTICITY	(PSI)	68	25330	±1278	5278	21	17666	16528	11.9
PARALLEL TENSION									
TENSILE STRENGTH	(PSI)	0	---	---	---	---	---	---	---
MODULUS OF ELASTICITY	(PSI)	0	---	---	---	---	---	---	---
SHEAR STRENGTH (AVERAGE)	(PSI)	34	484.5	±24.4	69.9	14.4	378.7	356.8	14.9
PERP. TENSILE STRENGTH	(PSI)	26	299.2	±23.3	57.8	19.3	214.4	205.5	38.1
CLEAVAGE LOAD PER INCH	(LBS)	56	141.3	±3.1	11.5	8.1	123.2	121.7	18.8
HARDNESS									
RAD AND TAN AVG.	(LBS)	60	320.7	±12.5	49.0	15.3	246.9	241.7	23.4
END	(LBS)	60	356.7	±9.9	38.5	10.8	297.0	292.6	8.3
NAIL WITHDRAWAL									
RAD AND TAN AVG.	(LBS)	16	109.1	±9.4	17.8	16.3	82.4	73.6	21.0
END	(LBS)	16	51.4	±4.7	8.9	17.2	38.3	36.4	84.4
SHRINKAGE									
VOLUMETRIC	(%)	19	11.9	±.67	1.4	11.7	9.82	9.19	25.2
RADIAL	(%)	22	4.67	±.27	.61	13.0	3.74	3.49	43.8
TANGENTIAL	(%)	32	7.58	±.27	.75	9.9	6.41	6.16	74.2
SPECIFIC GRAVITY		20	.369	±.01	.024	.065	.331	.320	37.7

TABLE D.3: WEIBULL DISTRIBUTION, GREEN WOOD

TEST TYPE	UNITS	OBSERVATIONS	MEAN	STANDARD DEVIATION	C.O.V. %	5% EXCLUSION LIMIT	χ^2
STATIC BENDING							
MODULUS OF RUPTURE	(PSI)	164	5281.8	493.4	9.3	4495.9	22.8
MODULUS OF ELASTICITY	(PSI)	164	1180053	211542	17.9	973524	4.02
PARALLEL COMPRESSION							
COMPRESSIVE STRENGTH	(PSI)	74	2802.3	267.8	9.6	2374.1	65.9
MODULUS OF ELASTICITY	(PSI)	74	1287293	319787	24.8	795484	151.4
PERPEND. COMPRESSION							
STRESS AT P.L.	(PSI)	68	241.3	44.4	18.4	178.3	11.3
STRESS AT .04"	(PSI)	68	381.5	55.7	14.6	301.8	25.2
MODULUS OF ELASTICITY	(PSI)	68	25333	4953	19.5	18135	11.81
PARALLEL TENSION							
TENSILE STRENGTH	(PSI)	0	---	---	---	---	---
MODULUS OF ELASTICITY	(PSI)	0	---	---	---	---	---
SHEAR STRENGTH (AVERAGE)	(PSI)	34	474.4	69.5	14.4	384.8	17.7
PERP. TENSILE STRENGTH	(PSI)	26	299.2	59.8	20.0	221.5	35.4
CLEAVAGE LOAD PER INCH	(LBS)	56	141.3	11.4	8.1	123.9	11.2
HARDNESS							
RAD AND TAN AVG.	(LBS)	60	320.6	48.0	15.0	246.3	50.1
END	(LBS)	60	356.7	38.7	10.8	301.7	25.1
NAIL WITHDRAWAL							
RAD AND TAN AVG.	(LBS)	16	109.1	18.7	17.2	83.5	17.8
END	(LBS)	16	51.5	12.10	23.5	40.3	72.5
SHRINKAGE							
VOLUMETRIC	(%)	19	11.9	1.4	11.7	10.06	34.8
RADIAL	(%)	22	4.67	.60	12.8	3.77	35.1
TANGENTIAL	(%)	32	7.58	.72	9.5	6.41	4.6
SPECIFIC GRAVITY		20	.369	.027	7.3	.340	26.1

TEST TYPE	UNITS	OBSERVATIONS	MEAN	95% CONFID. INTERVAL	STANDARD DEVIATION	C.O.V. %	5% EXCLUSION LIMIT	75% LOWER LIMIT	χ^2
TABLE D.4: NORMAL DISTRIBUTION, M.C. = 12%									
STATIC BENDING									
MODULUS OF RUPTURE	(PSI)	110	9507.0	±189.8	1003.3	10.6	7856.6	7754.4	13.9
MODULUS OF ELASTICITY	(PSI)	110	1513632	±41273	218143	14.4	1154786	1132578	13.9
PARALLEL COMPRESSION									
COMPRESSIVE STRENGTH	(PSI)	154	6324.6	±83.7	525.5	8.3	5460.1	5415.2	15.2
MODULUS OF ELASTICITY	(PSI)	153	1767075	±38833	243928	13.3	1380619	1360468	14.9
PERPEND. COMPRESSION									
STRESS AT P.L.	(PSI)	61	462.5	±16.8	65.5	14.2	354.7	339.7	2.5
STRESS AT .04"	(PSI)	61	725.5	±24.5	95.7	13.2	567.9	546.1	17.3
MODULUS OF ELASTICITY	(PSI)	61	46872	±1987	7761	16.6	34106	32334	6.2
PARALLEL TENSION									
TENSILE STRENGTH	(PSI)	52	13154.2	±798	2859.9	21.7	8449.7	8017.6	50.2
MODULUS OF ELASTICITY	(PSI)	51	1759821	±74551	262136	14.9	1328608	1288587	14.1
SHEAR STRENGTH (AVERAGE)	(PSI)	111	776.0	±21.1	112.3	14.5	591.2	579.9	10.3
PERP. TENSILE STRENGTH	(PSI)	107	396.1	±16.7	87.2	22.0	252.8	243.8	52.0
CLEAVAGE LOAD PER INCH	(LBS)	110	223.0	±4.4	23.4	10.5	184.5	182.1	5.4
HARDNESS									
RAD AND TAN AVG.	(LBS)	53	467.1	±14.3	51.8	11.1	381.9	374.2	18.4
END	(LBS)	53	549.9	±13.2	47.7	8.7	471.4	459.5	11.5
NAIL WITHDRAWAL									
RAD AND TAN AVG.	(LBS)	55	90.5	±5.4	19.9	22.0	57.8	54.8	52.7
END	(LBS)	55	52.5	±3.8	13.9	26.4	29.7	27.6	29.0
SHRINKAGE									
VOLUMETRIC	(%)	N/A	---	---	---	---	---	---	---
RADIAL	(%)	N/A	---	---	---	---	---	---	---
TANGENTIAL	(%)	N/A	---	---	---	---	---	---	---
SPECIFIC GRAVITY		20	.418	±.01	.031	7.4	.367	.354	19.6

TABLE D.5: LOG NORMAL DISTRIBUTION, M.C. = 12 %									
TEST TYPE	UNITS	OBSERVATIONS	MEAN	95% CONFID. INTERVAL	STANDARD DEVIATION	C.O.V. %	5% EXCLUSION LIMIT	75% LOWER LIMIT	χ^2
STATIC BENDING									
MODULUS OF RUPTURE	(PSI)	110	9506.4	±187.1	989.0	10.4	7971.7	7888	8.6
MODULUS OF ELASTICITY	(PSI)	110	1514124	±221483	1170630	15.0	1152936	1152936	33.9
PARALLEL COMPRESSION									
COMPRESSIVE STRENGTH	(PSI)	154	6324.4	±82.6	519.1	8.2	5508.3	5469	7.9
MODULUS OF ELASTICITY	(PSI)	153	1767404	±38490	241770	13.7	1399701	1383448	21.2
PERPEND. COMPRESSION									
STRESS AT P.L.	(PSI)	61	462.5	±16.9	66.1	14.3	362.4	347.3	2.5
STRESS AT .04"	(PSI)	61	725.5	±25.1	97.9	13.5	576.5	554.1	17.7
MODULUS OF ELASTICITY	(PSI)	61	46880	±2030	7929	16.9	35065	34257	6.0
PARALLEL TENSION									
TENSILE STRENGTH	(PSI)	52	13153.8	±798	2859.5	21.7	9026.3	8737.9	32.8
MODULUS OF ELASTICITY	(PSI)	51	1760127	76500	268986	15.3	1355134	1324061	16.8
SHEAR STRENGTH (AVERAGE)	(PSI)	111	776.1	±21.8	115.8	14.9	601.4	592.4	11.1
PERP. TENSILE STRENGTH	(PSI)	107	396.7	±18.0	94.1	23.7	262.7	256.4	37.9
CLEAVAGE LOAD PER INCH	(LBS)	110	223.0	±4.5	23.6	10.6	186.4	184.4	6.5
HARDNESS									
RAD AND TAN AVG.	(LBS)	53	467.0	±13.9	50.5	10.8	388.9	382.7	11.1
END	(LBS)	53	549.9	±13.0	47.2	8.6	475.9	464.1	8.5
NAIL WITHDRAWAL									
RAD AND TAN AVG.	(LBS)	55	90.4	±5.1	18.8	20.8	63.1	61.2	26.7
END	(LBS)	55	52.4	±3.6	13.4	25.5	33.6	32.4	9.9
SHRINKAGE									
VOLUMETRIC	(%)	N/A	---	---	---	---	---	---	---
RADIAL	(%)	N/A	---	---	---	---	---	---	---
TANGENTIAL	(%)	N/A	---	---	---	---	---	---	---
SPECIFIC GRAVITY		20	.418	±.01	.031	7.4	.369	.355	19.1

TABLE D.6: WEIBULL DISTRIBUTION M.C. = 12%							
TEST TYPE	UNITS	OBSERVATIONS	MEAN	STANDARD DEVIATION	C.O.V. %	5% EXCLUSION LIMIT	χ^2
STATIC BENDING							
MODULUS OF RUPTURE	(PSI)	110	9507.0	1026.0	10.8	8071.0	10.7
MODULUS OF ELASTICITY	(PSI)	110	1513632	216775	14.3	11638760	8.1
PARALLEL COMPRESSION							
COMPRESSIVE STRENGTH	(PSI)	154	6324.6	527.0	8.3	5561.0	17.2
MODULUS OF ELASTICITY	(PSI)	153	1767075	232868	13.2	13801040	33.8
PERPEND. COMPRESSION							
STRESS AT P.L.	(PSI)	61	462.5	66.7	14.4	363.6	5.2
STRESS AT .04"	(PSI)	61	725.4	76.7	10.5	585.7	16.4
MODULUS OF ELASTICITY	(PSI)	61	46872	8686	18.5	35604	14.6
PARALLEL TENSION							
TENSILE STRENGTH	(PSI)	52	13154.2	2938.0	22.3	9185.0	31.8
MODULUS OF ELASTICITY	(PSI)	51	1759821	263064	14.9	13716390	20.7
SHEAR STRENGTH (AVERAGE)	(PSI)	111	776.0	112.4	14.5	607.5	17.7
PERP. TENSILE STRENGTH	(PSI)	107	396.1	86.9	21.9	256.6	52.1
CLEAVAGE LOAD PER INCH	(LBS)	110	223.0	23.4	10.5	187.8	4.5
HARDNESS							
RAD AND TAN AVG.	(LBS)	53	467.1	52.8	11.3	393.5	17.5
END	(LBS)	53	549.9	49.3	8.9	480.1	13.1
NAIL WITHDRAWAL							
RAD AND TAN AVG.	(LBS)	55	90.5	22.9	25.4	65.9	15.9
END	(LBS)	55	52.5	14.8	28.1	34.1	93.6
SHRINKAGE							
VOLUMETRIC	(%)	N/A	---	---	---	---	---
RADIAL	(%)	N/A	---	---	---	---	---
TANGENTIAL	(%)	N/A	---	---	---	---	---
SPECIFIC GRAVITY		20	.418	.032	7.6	.375	18.9

APPENDIX E: DESIGN PROPERTY DEVELOPMENT WORKSHEETS

The tables contained in this appendix were used to develop the allowable design properties for Alaskan White Spruce given in this paper. These tables contain a summary of the defects permitted in a lumber grade, as governed by NELMA and WWPA rules. The tables also contain stress ratios representing the loss of strength due to the listed defects. In the last part of each table, the allowable design properties for the grade described in each particular table are given. The design values and composite correction factors used to obtain the values are summarized in Table E.16. More detailed explanations of these tables, the factors used, and explanations of the defects are given in Section 5.5.

In general, the stress ratios given in the tables where determined using charts and formulations provided by ASTM Document D245, titled "Standard Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber" (4). In some cases the D245 correction factors did not seem realistic, gave values that were either far too low, or did not follow strength trends indicated by other species listed in tables of design data, in particular the National Design Specification for Wood Construction (NDS). In these cases, alternate factors were developed; instances in which alternative factors were used are listed in the following table notes.

APPENDIX E TABLE NOTES:

1. Unless stated otherwise, all dimensions are in inches, all strength values are in psi, and modulus values are in million psi.

2. Values in parentheses () represent deviations from ASTM D245, which are used as noted in subsequent table notes.

3. In general, dimensions of knots given in tables apply to knots within the middle one-third of the length of the member. In the case of Beams and Stringers, knots in a member's narrow face at the ends of the member, are allowed to be twice the listed size, up to the knot size allowed for the center of the members wide face.

4. The Special Bending factor is determined using the width of the widest member in each grade category.

5. Tables E.1 through E.8 are developed with no deviations from ASTM D245.

6. Tables E.9 through E.11 follow NELMA/WWPA practice, in that bending strength values obtained for these grades apply only to the 4" nominal widths. Stress ratios for narrower widths are shown in parentheses for reference, but are not used in developing the allowable design values.

7. Table E.12 is used for the No.1 Beam and Stringer grade. NELMA/WWPA requires a beam be at least 5 inches thick, with the width at least 2 inches greater than the thickness. Thus, for the 5 and 6 inch sizes, nominal widths of 7 and 8 inches were used for the purposes of determining edge knot effects. NELMA/WWPA does not specify knot sizes for widths less than a nominal 8 inches, however it is believed the intent of the grading rules is to allow a 3 inch knot in the wide face of any member.

Knot size listed for the member's narrow face may be increased in size up to the knot size for the center of the wide face at the ends (see note #3). This results in 3 inch knots in 5 and 6 inch nominal faces at the ends of the beams. The resulting stress ratio given in the table for center of wide face in the 5 and 6 inch nominal widths applies only to compression and tension, as this defect is allowed only at the end of the beams. Thus, a stress ratio of .52 was found for bending in the middle of the beam, while a stress ratio of .34 was found for tension at the end of the beam.

8. Table E.13 is used for the No.2 Beam and Stringer grade. All notes given in #7 above apply to Table E.13, except a minimum knot size of 4.5 inches in the member centerline applies. No stress ratio for knot in centerline of wide face is given for the 5 inch nominal width, as in fact this involves a 4.5 inch knot in a 4.5 inch thick member; this timber is most likely unusable and would not be included in this grade. Note #10 also applies to Table E.13.

9. Tables E.14 and E.15 apply to the Post and Timber grades. NELMA/WWPA allows for knots of listed sizes anywhere and any face of the member. It is thus possible to have knots in all four faces of the member in a short section. Thus, for compression, the stress ratios for a knot in the narrow face, and the wide face were multiplied together to account for the possibility of multiple knots, and the worst case value used as the compression stress ratio. Note #10 also applies to Table E.15.

10. In some cases ASTM D245 corrections for knot at edge of wide face give stress ratios which seem extremely low. ASTM D245 indicates a member such as a 20 inch wide beam with a 10 inch knot possesses only 12 percent of the strength of a defect free member. However, mechanics of materials indicate that a loss of 50% of cross section results in 25% remaining strength. Furthermore, available tables of allowable design properties do not indicate the low strengths generated by ASTM D245 (25,26). Hence, the stress ratio of 25% was used for two groups of members affected by the low ASTM D245 values, the No.2 Beams and Stringers of Table E.13, and the No.2 Posts and Timbers of Table E.15. The ASTM D245 corrections are shown in parentheses ().

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.1: NO.1 STRUCTURAL JOISTS AND PLANKS

KNOT TYPE DEFECTS

NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		BENDING		COMPRESS
NOMINAL WIDTH	EDGE WIDE FACE	CENTERLINE WIDE FACE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
5	1.25	1.875	.57	.62	.62
6	1.5	2.25	.57	.62	.62
8	2	2.75	.57	.66	.66
10	2.5	3.25	.57	.69	.69
12	3	3.75	.57	.69	.69
14	3.125	4	.58	.69	.69
16	3.25	4.5	.60	.68	.68
18	3.375	4.625	.60	.68	.68

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.55			
MODULUS QUALITY	= 100%				
STRESS RATIO FROM ABOVE		.62	.62	.62	
SHAKE	1/2 THICKNESS				.55
SLOPE OF GRAIN	1 IN 10	.61	.61	.74	
SPLITS	= THICKNESS				.67
SPECIAL BENDING FACTOR	(2/18)^(1/9)	.7834			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.55	.7834	.2052	6525	1338	1350
TENSILE	2.1	.55 X .55		.1440	6225	939	950
SHEAR	4.1	.55		.134	538	72	70
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.62		.3263	3999	1304	1300
MODULUS	.94	1.0		1.064	1.347	1.433	1.40

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.2: NO.1 STRUCTURAL LIGHT FRAMING

KNOT TYPE DEFECTS

NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		BENDING		COMPRESS
NOMINAL WIDTH	EDGE WIDE FACE	CENTERLINE WIDE FACE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
2	.5	.5	.65	.86	.86
3	.75	.75	.57	.79	.79
4	1	1.5	.57	.57	.57

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.55			
MODULUS QUALITY	= 100%				
STRESS RATIO FROM ABOVE		.57	.57	.57	
SHAKE	1/2 THICKNESS				.55
SLOPE OF GRAIN	1 IN 10	.61	.61	.74	
SPLITS	= THICKNESS				.67
SPECIAL BENDING FACTOR	(2/4)^(1/9)	.9258			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.55	.9258	.2425	6525	1582	1550
TENSILE	2.1	.55 X .55		.1440	6225	939	950
SHEAR	4.1	.55		.134	538	72	70
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.57		.30	3999	1199	1200
MODULUS	.94	1.0		1.064	1.347	1.433	1.40

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.3: NO.2 STRUCTURAL JOISTS AND PLANKS

KNOT TYPE DEFECTS

NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		BENDING		COMPRESS
NOMINAL WIDTH	EDGE WIDE FACE	CENTERLINE WIDE FACE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
5	1.625	2.375	.50	.52	.52
6	1.875	2.875	.48	.52	.52
8	2.5	3.5	.48	.57	.57
10	3.25	4.25	.48	.58	.58
12	3.75	4.75	.48	.61	.61
14	4.125	5.25	.48	.60	.60
16	4.25	5.75	.48	.59	.59
18	4.375	5.875	.48	.59	.59

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.45			
MODULUS QUALITY	= 90%				
STRESS RATIO FROM ABOVE		.48	.48	.52	
SHAKE	1/2 THICKNESS				.55
SLOPE OF GRAIN	1 IN 8	.53	.53	.66	
SPLITS	= 1.5 X THICKNESS				.50
SPECIAL BENDING FACTOR	(2/18)^(1/9)	.7834			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.45	.7834	.1679	6525	1095	1100
TENSILE	2.1	.45 X .55		.1179	6525	769	775
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.52		.2737	3999	1094	1100
MODULUS	.94	.90		.9574	1.347	1.289	1.30

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.4: NO.2 STRUCTURAL LIGHT FRAMING

KNOT TYPE DEFECTS

NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		BENDING		COMPRESS
NOMINAL WIDTH	EDGE WIDE FACE	CENTERLINE WIDE FACE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
2	.625	.625	.47	.49	.49
3	.875	.875	.47	.49	.49
4	1.25	2	.47	.49	.49

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.45			
MODULUS QUALITY	= 90%				
STRESS RATIO FROM ABOVE		.47	.47	.49	
SHAKE	1/2 THICKNESS				.55
SLOPE OF GRAIN	1 IN 8	.53	.53	.66	
SPLITS	= THICKNESS				.50
SPECIAL BENDING FACTOR	(2/4)^(1/9)	.9258			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.45	.9258	.1984	6525	1294	1300
TENSILE	2.1	.45 X .55		.1179	6525	769	775
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.49		.2579	3999	1031	1050
MODULUS	.94	.90		.9574	1.347	1.289	1.30

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.5: NO.3 STRUCTURAL JOISTS AND PLANKS

KNOT TYPE DEFECTS

NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		BENDING		COMPRESS
NOMINAL WIDTH	EDGE WIDE FACE	CENTERLINE WIDE FACE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
5	2.25	3	.28	.34	.34
6	2.75	3.75	.28	.32	.32
8	3.5	4.5	.28	.41	.41
10	4.5	5.5	.28	.45	.45
12	5.5	6.5	.28	.46	.46
14	6	7	.28	.46	.46
16	6.375	8	.29	.42	.42
18	6.5	8.25	.30	.43	.43

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.26			
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE		.28	.28	.32	
SHAKE	THROUGH				.50
SLOPE OF GRAIN	1 IN 4	.26	.26	.40	
SPLITS	= 1/6 LENGTH				.50
SPECIAL BENDING FACTOR	(2/18)^(1/9)	.7834			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.26	.7834	.0969	6525	632.8	625
TENSILE	2.1	.26 X .55		.0681	6525	444.3	450
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.32		.1684	3999	673.5	675
MODULUS	.94	.80		.8511	1.347	1.146	1.10

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.6: NO.3 STRUCTURAL LIGHT FRAMING

KNOT TYPE DEFECTS

NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		BENDING		COMPRESS
NOMINAL WIDTH	EDGE WIDE FACE	CENTERLINE WIDE FACE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
2	.75	.75	.27	.52	.52
3	1.25	1.25	.27	.52	.52
4	1.75	2.5	.28	.30	.30

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.26			
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE		.27	.27	.30	
SHAKE	THROUGH				.50
SLOPE OF GRAIN	1 IN 4	.26	.26	.40	
SPLITS	1/6 LENGTH				.50
SPECIAL BENDING FACTOR	(2/4)^(1/9)	.9258			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.26	.9258	.1146	6525	747.9	700
TENSILE	2.1	.26 X .55		.0681	6525	444.3	450
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.30		.1578	3999	631.4	625
MODULUS	.94	.80		.851	1.347	1.146	1.10

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.7: STUD GRADE STRUCTURAL JOISTS AND PLANKS

KNOT TYPE DEFECTS

NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		BENDING		COMPRESS
NOMINAL WIDTH	EDGE WIDE FACE	CENTERLINE WIDE FACE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
5	2.25	3	.28	.34	.34
6	2.75	3.75	.28	.32	.32

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.26			
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE		.28	.28	.32	
SHAKE	THROUGH				.50
SLOPE OF GRAIN	1 IN 4	.26	.26	.40	
SPLITS	= 2 X WIDTH				.50
SPECIAL BENDING FACTOR	(2/18)^(1/9)	.8851			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.26	.8851	.1096	6525	715	700
TENSILE	2.1	.26 X .55		.0681	6525	444	450
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.32		.1684	3999	673	675
MODULUS	.94	.80		.8510	1.347	1.146	1.10

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.8: STUD GRADE STRUCTURAL LIGHT FRAMING

KNOT TYPE DEFECTS

NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		BENDING		COMPRESS
NOMINAL WIDTH	EDGE WIDE FACE	CENTERLINE WIDE FACE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
2	.75	.75	.27	.62	.62
3	1.25	1.25	.27	.58	.58
4	1.75	2.5	.28	.30	.30

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.26			
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE		.27	.27	.30	
SHAKE	THROUGH				.50
SLOPE OF GRAIN	1 IN 4	.26	.26	.40	
SPLITS	2 X WIDTH				.50
SPECIAL BENDING FACTOR	(2/4)^(1/9)	.9258			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.26	.9258	.1146	6525	747	750
TENSILE	2.1	.26 X .55		.0681	6525	444	450
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.30		.1578	3999	631	625
MODULUS	.94	.80		.8510	1.347	1.146	1.10

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.9: CONSTRUCTION GRADE LIGHT FRAMING

KNOT TYPE DEFECTS

NELMA/WWPA RULES		STRESS RATIOS		
	KNOT AT	BENDING		COMPRESS
NOMINAL WIDTH	ANYWHERE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
2	.75	(.27)	.53	.53
3	1.25	(.28)	.52	.52
4	1.5	.34	.62	.62

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.34			
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE		.34	.34	.52	
SHAKE	NONE THROUGH				.50
SLOPE OF GRAIN	1 IN 6	.40	.40	.56	
SPLITS	THICKNESS				.67
SPECIAL BENDING FACTOR	(2/4)^(1/9)	.9258			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.34	.9258	.1499	6525	978	975
TENSILE	2.1	.34 X .55		.0890	6525	581	575
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.52		.2736	3999	1094	1100
MODULUS	.94	.80		.8510	1.347	1.146	1.10

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.10: STANDARD GRADE LIGHT FRAMING

KNOT TYPE DEFECTS

NELMA/WWPA RULES		STRESS RATIOS		
	KNOT AT	BENDING		COMPRESS
NOMINAL WIDTH	ANYWHERE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
2	1	(.13)	.36	.36
3	1.5	(.17)	.42	.42
4	2	.19	.49	.49

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.19			
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE		.19	.19	.49	
SHAKE	1/2 THICKNESS				.50
SLOPE OF GRAIN	1 IN 4	.26	.26	.40	
SPLITS	1.5 X WIDTH				.50
SPECIAL BENDING FACTOR	(2/4)^(1/9)	.9258			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.19	.9258	.0837	6525	546	550
TENSILE	2.1	.19 X .55		.0497	6525	325	325
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.40		.2105	3999	841	850
MODULUS	.94	.80		.8510	1.347	1.146	1.10

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.11: UTILITY GRADE LIGHT FRAMING

KNOT TYPE DEFECTS

NELMA/WWPA RULES		STRESS RATIOS		
	KNOT AT	BENDING		COMPRESS
NOMINAL WIDTH	ANYWHERE	DUE TO EDGE KNOT	DUE TO CENTERLINE KNOT	DUE TO KNOT ANYWHERE
2	1.25	(.037)	.19	.19
3	2	(.046)	.22	.22
4	2.5	.09	.30	.30

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
GRADE DEFINITION		.09			
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE		.09	.09	.30	
SHAKE	AS SPLITS				.50
SLOPE OF GRAIN	1 IN 4	.26	.26	.40	
SPLITS	1/6 LENGTH				.50
SPECIAL BENDING FACTOR	(2/4)^(1/9)	.9258			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.09	.9258	.0428	6525	279	250
TENSILE	2.1	.09 X .55		.0235	6525	154	150
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.30		.1578	3999	631	625
MODULUS	.94	.80		.8510	1.347	1.146	1.10

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.12: NO.1 BEAMS AND STRINGERS

KNOT TYPE DEFECTS

NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		DUE TO KNOT AT:		
WIDTH OR THICKNESS	NARROW & EDGE WIDE	CENTER WIDE	EDGE OF NARROW	EDGE OF WIDE	CENTER OF WIDE
5	1.875	(3)	.62	(.54)	(.34)
6	2.25	(3)	.62	(.52)	(.46)
8	2.625	3	.62	.54	.63
12	3.25	4.5	.62	.54	.63
14	3.5	4.875	.62	.54	.62
16	3.75	5.25	.62	.54	.62
18	4.125	5.625	.62	.55	.62
20		5.875		.55	.62
22		6.125		.56	.62
24		6.375		.57	.63

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE		.52	.34	.34	
SHAKE	1/6 THICKNESS				.65
SLOPE OF GRAIN	1 IN 11	.65	.65	.78	
SPLITS	WIDTH				.50
SPECIAL BENDING FACTOR	(2/24)^(1/9)	.7587			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOWABLE	ROUNDED
BENDING	2.1	.52	.7587	.1875	6525	1226	1200
TENSILE	2.1	.34 X .55		.0909	6525	581	600
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.34		.1789	3999	715	725
MODULUS	.94	.80		.8510	1.347	1.146	1.10

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT TABLE E.13: NO.2 BEAMS AND STRINGERS					
KNOT TYPE DEFECTS					
NELMA/WWPA RULES			STRESS RATIOS		
	KNOT AT		DUE TO KNOT AT:		
WIDTH OR THICKNESS	NARROW & EDGE WIDE	CENTER WIDE	EDGE OF NARROW	EDGE OF WIDE	CENTER OF WIDE
5	2.625	(4.5)	.42	(.32)	(—)
6	3.25	(4.5)	.45	(.32)	(.189)
8	4.5	4.5	.41	(.20)	.40
12	6.875	6.875	.40	(.16)	.41
14	8.125	7.625	.40	(.13)	.40
16	9.125	8.125	.41	(.11)	.41
18	9.625	8.625	.45	(.11)	.41
20	10	9.125	.49	(.12)	.41
22		9.625			.40
24		10			.41

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS					
ITEM	EXTENT	BENDIN G	TENSION	COMPRE S	SHEAR
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE	NOTE: USED MECH. OF MAT.	(.25)	.189	.189	
SHAKE	1/2 LENGTH 1/2 THICK				.50
SLOPE OF GRAIN	1 IN 6	.40	.40	.56	
SPLITS	MEDIUM				.50
SPECIAL BENDING FACTOR	(2/24)^(1/9)	.7587			

DESIGN PROPERTY CALCULATIONS							
PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOS-ITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.25		.1190	6525	776	775
TENSILE	2.1	.19 X .55		.0497	6525	324	325
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.19		.10	3999	399	400
MODULUS	.94	.80		.8510	1.347	1.146	1.10

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT TABLE E.14: NO.1 POSTS AND TIMBERS					
KNOT TYPE DEFECTS					
NELMA/WWPA RULES		STRESS RATIOS			
	KNOT	BENDING		COMPRESSION	
WIDTH WIDE FACE	ANYWHERE	CENTER NARROW	EDGE OF WIDE	CENTERLINE NARROW	CENTERLINE WIDE
5	1.5	.49	.49	.70	.70
6	1.875	.52	.48	.62	.69
8	2.5	.58	.48	.58	.69
10	3.125	.55	.48	.61	.69
12	3.75	.54	.48	.63	.69
14	4	.55	.48	.67	.69
16	4.25	.54	.48	.63	.70
18	4.5	.55	.49	.68	.70

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS					
ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE		.48	.48	.58&.69	
SHAKE	1/2 LENGTH 1/2 THICK				.50
SLOPE OF GRAIN	1 IN 10	.61	.61	.74	
SPLITS	= WIDTH				.50
SPECIAL BENDING FACTOR	(2/18^(1/9)	.7833			

DESIGN PROPERTY CALCULATIONS							
PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOS-ITE	CLEAR WOOD	ALLOW ABLE	ROUNDED
BENDING	2.1	.48	.7833	.1790	6525	1168	1100
TENSILE	2.1	.48 X .55		.1257	6525	820	825
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.58 X .69		.2106	3999	842	850
MODULUS	.94	.80		.8510	1.347	1.146	1.10

ALASKAN WHITE SPRUCE: ALLOWABLE PROPERTY DEVELOPMENT

TABLE E.15: NO.2 POSTS AND TIMBERS

KNOT TYPE DEFECTS

NELMA/WWPA RULES		STRESS RATIOS			
	KNOT	BENDING		COMPRESSION	
WIDTH WIDE FACE	ANYWHERE	CENTER NARROW	EDGE OF WIDE	CENTERLINE NARROW	CENTERLINE WIDE
5	2.25	.55	.26	.55	.55
6	2.75	.40	.26	.40	.54
8	3.75	.33	.26	.32	.54
10	4.75	.37	.26	.37	.53
12	5.75	.40	.25	.40	.52
14	6.75	.42	(.22)	.43	.47
16	7.75	.43	(.19)	.39	.43
18	8.75	.43	(.17)	.36	.40

MISCELLANEOUS NELMA/WWPA DEFECTS AND ADJUSTMENTS

ITEM	EXTENT	BENDING	TENSION	COMPRES	SHEAR
MODULUS QUALITY	= 80%				
STRESS RATIO FROM ABOVE		.26	.26	.36,.40	
SHAKE	1/2 LENGTH 1/2 THICK				.50
SLOPE OF GRAIN	1 IN 6	.40	.40	.56	
SPLITS	MEDIUM				.50
SPECIAL BENDING FACTOR	(2/18^(1/9)	.7833			

DESIGN PROPERTY CALCULATIONS

PROPERTY	ADJUSTMENT FACTORS				WOOD STRENGTH VALUE		
	GENERAL	STRESS RATIO	SPECIAL FACTOR	COMPOSITE	CLEAR WOOD	ALLOWABLE	ROUNDED
BENDING	2.1	.26	.7833	.0969	6525	632	625
TENSILE	2.1	.26 X .55		.0681	6525	444	450
SHEAR	4.1	.50		.1219	538	65.6	65
PERP. COMP.	1.67	1.0		.5988	537	321	320
PARA. COMP	1.9	.36 X .40		.0757	3999	303	300
MODULUS	.94	.80		.8510	1.347	1.146	1.10

TABLE E.16: ROUNDED DESIGN VALUES AND COMPOSITE ADJUSTMENT FACTORS

GRADE	SIZE	DESIGN VALUES IN POUNDS PER SQUARE INCH					
		BENDING "F_b"	TENSION PARALLEL TO GRAIN "F_t"	HORIZONTAL SHEAR "F_v"	COMPRESSION PERPENDICULAR TO GRAIN "$F_{c\perp}$"	COMPRESSION PARALLEL TO GRAIN "F_c"	MODULUS OF ELASTICITY "E"
STRUCTURAL FRAMING							
NO.1	2" TO 4" THICK	1550 .2425	950 .1440	70 .134	320 .5988	1200 .30	1,400,000 1.064
NO.2	2" TO 4" WIDE	1300 .1984	775 .1179	65 .1219	320 .5988	1050 .2579	1,300,000 .9574
NO.3		700 .1146	450 .0681	65 .1219	320 .5988	625 .1578	1,100,000 .851
STUD		750 .1146	450 .0681	65 .1219	320 .5988	625 .1578	1,100,000 .851
LIGHT FRAMING							
CONSTRUCT	2" TO 4" THICK	975 .1499	575 .0890	65 .1219	320 .5988	1100 .2736	1,100,000 .851
STANDARD	4" WIDE	550 .0837	325 .0497	65 .1219	320 .5988	850 .2105	1,100,000 .851
UTILITY		250 .0428	150 .0235	65 .1219	320 .5988	625 .1578	1,100,000 .851
JOISTS AND PLANKS							
NO.1	2" TO 4" THICK	1350 .2052	950 .1440	70 .134	320 .5988	1300 .3263	1,400,000 1.064
NO.2	5" AND WIDER	1100 .1679	775 .1179	65 .1219	320 .5988	1100 .2737	1,300,000 .9574
NO.3		625 .0969	450 .0681	65 .1219	320 .5988	675 .1684	1,100,000 .8511
STUD	6" WIDE	700 .1096	450 .0681	65 .1219	320 .5988	675 .1684	1,100,000 .851
BEAMS AND STRINGERS							
NO.1	5" AND WIDER	1200 .1875	600 .0909	65 .1219	320 .5988	725 .1789	1,100,000 .851
NO.2	DEPTH ≥ WIDTH+2"	775 .1190	325 .0497	65 .1219	320 .5988	400 .10	1,100,000 .851
POSTS AND TIMBERS							
NO.1	5" AND WIDER	1100 .1790	825 .1257	65 .1219	320 .5988	850 .2106	1,100,000 .851
NO.2	DEPTH ≥ WIDTH+2"	625 .0969	450 .0681	65 .1219	320 .5988	300 .0758	1,100,000 .851